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PENNSYLVANIA
GEOLOGICAL SURVEY
FOURTH SERIES

TOPOGRAPHIC AND GEOLOGIC
ATLAS
of
PENNSYLVANIA

NO. 5

NEW CASTLE QUADRANGLE

GEOLOGY AND MINERAL RESOURCES

By
F. W. DEWOLF

Prepared in cooperation with the United States Geological Survey

Department of Internal Affairs
Jas. F. Woodward, Secretary

Topographic and Geologic Survey
George H. Ashley, State Geologist

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LETTER OF TRANSMITTAL

Hon. James F. Woodward,
Secretary, Dept. of Internal Affairs,
Harrisburg, Pennsylvania.

Sir:

I have the honor to transmit herewith manuscript, maps and illustrations for a Topographic and Geologic Atlas of the New Castle region.

This is a report of a detailed study of the geology and mineral resources of the New Castle quadrangle, made by the State in cooperation with the U. S. Geological Survey. It was originally made by Mr. Frank W. DeWolf under my supervision in 1905. However, Mr. DeWolf was called to the position of State Geologist of Illinois before completing his report. Pressure of duties in his new position prevented his completing the project.

Nearly two years ago at my request, all the material was turned over to this Survey, and it has finally been prepared by members of this Survey, the work involving a small amount of additional field work. Mr. Corbin and Mr. Stone have each had a hand in the final preparation of the report, the maps and the illustrations.

Respectfully submitted,

Geo. H. Ashley

State Geologist.

September 23, 1927.

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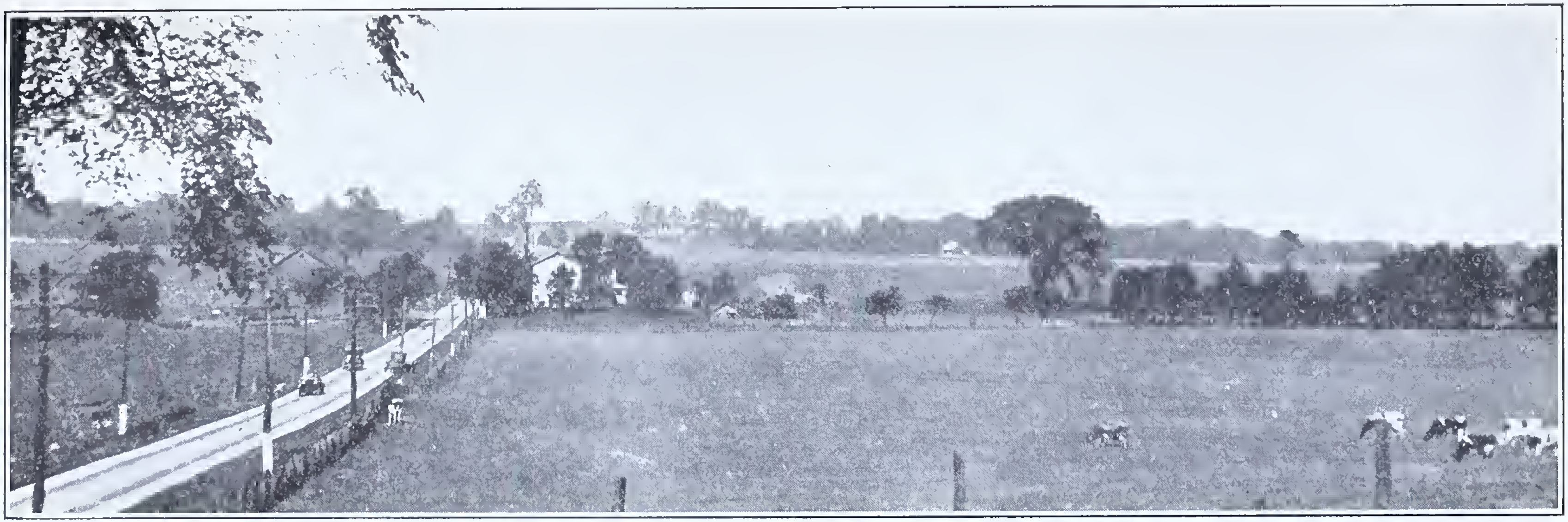

Upland topography near Energy

GEOLOGY AND MINERAL RESOURCES OF THE NEW CASTLE QUADRANGLE

By F. W. DeWolf.

INTRODUCTION

Location and Area

The area embraced by this report, as indicated by Figure 1, is along the western border of Pennsylvania about equally distant from the north and south margins. It includes the New Castle quadrangle and, in addition, a strip about one mile wide between the western boundary of the quadrangle and the Pennsylvania-Ohio State line on the

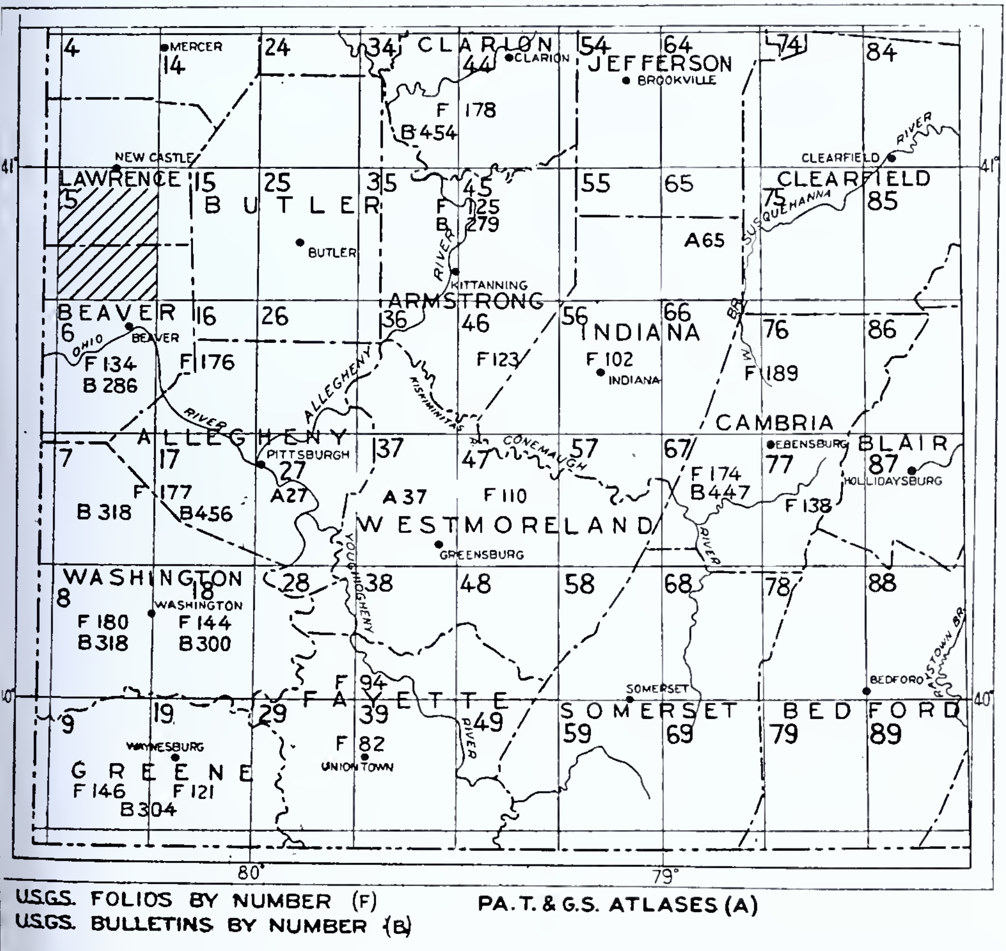

FIGURE 1. Outline map of Western Pennsylvania, showing location of New Castle quadrangle.

west. The district extends from longitude 80° 15′ W to the Pennsylvania-Ohio State line (approx. long. 80° 31′ W) and from latitude 40° 45′ N to 41° 00′ N. The included area is about 245 square miles of which a little over one-half lies in Lawrence county and the remainder in Beaver County.

The topographic and cultural features, streams, settlements, railroads, and highways, are shown on the Topographic Map, Plate I, accompanying this report. A mantle of loose, unconsolidated foreign material deposited on the surface by invasions of ice sheets (Pl. II, Surficial Geologic Map) masks much of the underlying bedded deposits (Pl. III, Areal Geologic Map). Economic developments, exclusive of those of oil and gas, are so numerous that their relations are shown separately (Pl. IV, Economic Geologic Map). The oil and gas developments constitute a special phase, and are illustrated by the Oil and Gas Map, Pl. V.

Shenango and Mahoning rivers join in the north-central part of the area, forming Beaver River which flows southward. Connoquenessing Creek, after pursuing a very winding westerly course, enters Beaver River in the east-central part of the area. Little Beaver Creek, with its tributaries, drains the western part of the area.

The largest settlements within the area, New Castle and Beaver Falls, are in the valley of Beaver River. These cities are at the northern and southern boundaries of the quadrangle. As is shown later in this report the geologic features exercised complete control of the human activities and settlements within the area. The cities and larger towns are along or near the main drainage channels. The upland areas are sparsely settled, the land so located being used for agricultural pursuits.

The following table presents data concerning the population of the settlements within this area:

Population of cities and boroughs of New Castle quadrangle.

Place	1910 U. S. Census	1920 U. S. Census	1926 Estimated
Lawrence County			
Bessemer	†	1,417	2,000
Ellwood City*	3.902	8,958	11,361
Hazeldell	1,168	--------	--------
Enon Valley	354	359	362
New Castle	36,280	44,938	50,288
Wampum	980	882	960
Beaver County			
Beaver Falls	12,191	12,802	13,180
College Hill	1,787	2,643	3,172
Darlington	311	347	369
Eastvale	322	429	495
Homewood	†	310	--------
Koppel	†	762	--------
New Galilee	453	475	489
Patterson Heights	367	459	516

*Hazeldell annexed to Ellwood City between 1910 and 1920. Census figures not available for numerous other settlements within the area.

† Not incorporated.

Of the many industries represented in the area the mining industries are scattered; only the manufacturing industries are segregated in the cities and larger towns. The chief industries of the larger settlements follow:

New Castle: Steel and iron manufacturing; cement plants; engine works; tin plate mill; boiler and tank works; bolt, nut and rivet works; brass and iron foundries; car works; chemical works; stove and range works; chair, box and crate manufacturing companies; pottery, enamel ware, brick and glass works; extract works; cement building block works; planing mills; flour mills.

Mahoningtown: Railroad car repair shops; cement.

Bessemer: Limestone; paving brick; face brick; Portland cement.

West Pittsburgh: Nut and rivet works; conduit plants; radiator works; silk mill; pipe and tubing.

Ellwood City: Tube works, castings and forgings; machinery; elevators and hoists; wire products; nails and spikes; paving brick; enamel signs; engine and pump packing.

Wampum and Crescentdale: Limestone, portland cement, cement tile, artificial stone.

Koppel: Railroad car shops, building stone quarry.

Beaver Falls: Steel works; machine tool, axe, shovel and saw works; pottery, tile, glass and brick works; sash and door factory; asbestos protected metal works; planing mills.

College Hill: Scale, bridge, enamel ware, cork and tube works; Geneva College.

Darlington: Brick, agricultural community center.

New Galilee: Nurseries; car repair shops; face, standard, and ornamental brick; center of agricultural community.

In addition to these larger industries the communities are well supplied by local grocers, butchers, bakers, drug stores, garages, department stores, and other similar agencies which are deemed necessary to our present civilization. Printing establishments are to be found in the larger communities, and several newspapers are published in Beaver Falls and New Castle.

Electric power lines.

Of vast importance to the communities and to the development of an area are the electric power lines which cross it. In this respect the New Castle area is fortunately situated. Transmission lines of large systems and of smaller local systems bountifully supply customers within the area.

At Lowellville, Ohio, just northwest of this area, the Pennsylvania-Ohio Electric Company has a steam generating station of 60,000 k. w. capacity. Two transmission lines, 22-kv each, connect the Lowellville station with the New Castle 4050-kv-a substation. One of these lines continues to Ellwood City, where there is a 10,875-kv-a's substation. The Pennsylvania-Ohio Electric Company sells current to the Garland Manufacturing Company, who distributes it in West Pittsburgh. This is tapped from the New Castle-Ellwood City transmission line. At Ellwood City there is also a 250-kw. hydroelectric plant. From a point south of Ellwood City a 22-kv. line connects with Homewood and Enon Valley. Bessemer is served by a 66-kv. line from the station at Lowellville.

Darlington and New Galilee are served by the Harmony Electric Company, which has a line along the valley of Little Beaver Creek. The Harmony Electric Company serves Morado and the territory northward along the Beaver Valley. At Morado the lines of the Harmony Electric Company are connected with those of the Duquesne Light & Power Company, from whom they purchase current.

The area south of Morado along the Beaver Valley is served by the Duquesne Light & Power Company. The current which they distribute is not generated locally, but is transmitted from other interconnected stations of this company.

Transportation.

The New Castle region is well served with transportation agencies. Formerly the Pittsburgh and Erie canal passed through this area, but, being abandoned many years ago, it is no longer useful. Railroads follow all the larger valleys, however, and highways, constantly improved and extended, offer cross-country connections for bus lines and privately owned vehicles.

Railroads. The New York Central, Delaware & Hudson, Baltimore & Ohio, and the Pennsylvania railroad companies own and operate lines within the New Castle area. The Pittsburgh, Lisbon & Western Railroad, formerly controlled by the Wheeling & Lake Erie Railroad, now operates independently.

The Pittsburgh & Lake Erie Railroad (New York Central Lines) is located along the western bank of Beaver River between Beaver Falls and Irish Ripple. About half a mile north of Irish Ripple the road crosses Beaver River to the east side, crossing the Shenango at Mahoningtown and ascending the Mahoning.

The Delaware & Hudson system is represented by the Buffalo, Rochester & Pittsburgh Railroad which follows the valley of Big Run eastward from New Castle.

The Pennsylvania Railroad serves the territory through the Pittsburgh, Youngstown & Ashtabula Division, on the east side of Beaver River to Wampum, where it crosses to the west side, crossing the Mahoning twice near Mahoningtown, and following Mahoning River on the southwestern bank; through the Erie & Pittsburgh Division, which is built upon river benches on the west side of Beaver River, crossing Mahoning River one mile south of Mahoningtown, and following Shenango River along the west bank; and through the Pittsburgh, Ft. Wayne & Chicago, which connects western territory with the Pennsylvania Railroad tracks at Wampum. This railroad follows the south bank of Clarks Run, over "Summit cut," along a tributary of Little Beaver Creek to the valley of the latter, and serving New Galilee, Enon Valley, East Palestine, Ohio, and other points westward.

The Baltimore & Ohio Railroad (Pittsburgh and Chicago Lines) follows the valley of Connoquenessing Creek to Beaver River which it ascends along the eastern bank. Crossing the Shenango a mile above its junction with Mahoning River, the Baltimore & Ohio tracks ascend the latter valley. From New Castle Junction, two miles south of New Castle, a branch runs to New Castle. By this branch, connection to the B. R. & P. also is had.

The Pittsburgh, Lisbon & Western Railroad follows the valley of Little Beaver Creek to Negley, Ohio. It serves New Galilee, Darlington, and Cannelton, handling the brick, clay, and coal traffic originating in this region. In the years 1904-1916 this road was controlled by the Wheeling & Lake Erie, but control was relinquished in 1916.

Highways. The New Castle area is well served by a network of roads (See Plate I). Of these the most important, and the best constructed, are the State highways and County roads. Very few places within the area are more than two miles from an important improved road. Naturally, the highways converge at the larger settlements.

From New Castle Routes 79 and 315 have a southeast direction. Route 79, the northern of the two, leads to important points on the adjoining eastern (Zelienople) quadrangle. Route 315 connects with Ellwood City, at which place two unimproved State highways lead eastward, an improved County road connects with Chewton, and another improved County road connects with Eastvale and places farther south.

From New Castle Route 77 follows the west side of Beaver River Valley southward to Beaver Falls and beyond. Where this route crosses Mahoning River, at Mahoningtown, Route 265 branches westward to Mount Jackson, thence southward to Enon Valley. From Mount Jackson an improved County road leads westward to Bessemer; the road continues westward beyond the State line but has been improved only to Bessemer.

Between Enon Valley and New Galilee the State highway is unimproved. Route 354, partially improved, connects New Galilee with Route 77. A State highway also connects New Galilee and Darlington.

The "Darlington Road," Route 204, connects Beaver Falls and Patterson with Darlington. From the latter point it continues westward to the State line, about one mile east of New Palestine, Ohio.

The importance of this highway system is manifold. The advantages to the many agriculturists are evident, and both freight and passenger busses use the improved roads. Another use, growing in importance, is that of an avenue for the transportation of mineral products. Several coal mines along Bennett Run transport their entire output by motor trucks. The product of the stripping operation of the Beaver Finance Corporation, near the State line, having a minimum of 100 tons a day, is transported entirely by motor trucks. Operations of this character give a new significance to the utility of concrete roads to industries.

In addition to the State and County highways other roads are numerous, forming a veritable network over the area. A few of these have been surfaced with cinders, but by far the greater number of them are dirt roads. In fair weather these are easily traveled; in foul weather, however, they soon become pitted with mud-holes. Travel is particularly difficult where outcrops of some of the clays or shales occur, the resulting mud or clay being extremely slippery, affording poor traction. Up to the present it has been uneconomical to greatly improve such roads, although some attention has been paid to the drainage of them.

Aeronautics. As yet there is no aeronautical station within the area. There are many localities, however, where the terrane offers excellent opportunities for such development. Large level areas are to be found both in the river valleys and in the uplands, and each of these groups has advantages and disadvantages which are typical. As a rule the soil at favorable situations in the valleys is well drained; it would furnish excellent sod. The upland areas, on the contrary, frequently exhibit clayey or shaly soils whose sod would be easily destroyed by landing abrasions. The upland areas, on the other hand, have somewhat superior atmospheric conditions.

Generally speaking, the hazes, fogs, and mists are somewhat more frequent in the western part of Pennsylvania than in the eastern part. The low-lying valley areas, but slightly more elevated than the streams (which are frequently turbulent) are subject to these hazards to greater extent than the upland areas; but in no case are the objections so serious as to be prohibitive. Experience has taught that locations adjacent to steep cliffs are to be avoided, if possible, because of the disturbed atmospheric conditions, resulting in "air pockets," which prevail in such locations.

Emergency landings may be made at almost any locality within the area.

Canal. For several years a serious attempt has been made to rejuvenate the Pittsburgh-Lake Erie canal. Study of this problem has included not only the canal route but also all other important related subjects, such as traffic and future developments, which might reasonably be effective in contributing tonnage to be carried by the proposed canal. The route at present indicated follows those portions of Beaver and Mahoning rivers embraced within this area.

Federal aid has been sought in this project. Officers from the Engineering Corps, U. S. Army, were appointed to study various phases of the subject. Their first report questioned the economics of the project. Public hearings were held (December, 1925) and it is regarded probable that the next Congress will be called upon to decide what action, if any, is to be taken.

Mineral Products.

For over half a century mines, quarries, and factories have been developing the mineral wealth of this region. The mining of coal has perhaps taken first rank. Limestone quarries have been extensively worked to supply the demands of blast furnaces, lime kilns, railroads, highways, and cement plants. Sandstone for heavy building has been quarried at numerous localities along the Beaver Valley; clay and shale have given rise to important industries; and iron ore, in the early days, was an important product. About 1100 known wells have been drilled for oil and gas, and in many cases the efforts have been highly remunerative. Except iron ore, which is no longer mined, all of these mineral deposits are being worked more successfully today than ever before and the supply will last for many years.

Former Geologic Work.

Acknowledgment is here made of the valuable assistance derived in the present work from the reports of Dr. I. C. White, contained in Second Geological Survey of Pennsylvania Vols. Q and QQ, 1875 and 1877. These cover Beaver and Lawrence counties, reporting on the stratigraphy, structure, and economic features in considerable detail.

This Report.

The present report embodies the results of about four months of field work by the writer during 1905-06. Investigation was made of the geology of the region with reference both to purely scientific problems and to the economic features. The present atlas aims to cover the points necessary for an understanding of the economic resources of the region and to omit, as far as possible, those aspects which, though valuable to the scientist, are of slight importance or interest to the producer.

The geologic mapping and other field investigations for this report were done when the writer was a member of the United States Geological Survey. The work was carried on under a cooperative agreement between the U. S. Geological Survey and the Topographic and Geologic Survey Commission of Pennsylvania, and was under the supervision of George H. Ashley, the present State Geologist, in Pennsylvania, then a member of the U. S. Geological Survey. In 1908 the writer resigned from Federal service to become Assistant State Geologist of Illinois. His duties in that position and as director of the Illinois Geological Survey from 1911 to 1923 prevented completion of the report until 1925.

At the request of George H. Ashley, State Geologist of Pennsylvania, the United States Geological Survey, which lacked adequate funds for printing, surrendered all rights in the manuscript and maps to the Pennsylvania Topographic and Geologic Survey.

The manuscript has been brought up to date by J. Ross Corbin, associate geologist of the Pennsylvania Survey. Mr. Corbin visited the area in the fall of 1925 to bring the industrial part of the report up to date. He is mainly responsible for certain chapters of the report, especially those dealing with petroleum and natural gas, and water supplies and for the completion of the maps, and general rearrangement of the report. Once the area was visited by Mr. A. E. Fath of the U. S. Geological Survey to gather additional information on the oil and gas fields. The area was also visited by Messrs. R. R. Hice and F. B. Peck in 1919, to study quarry sites for limestone for road building, and by Mr. Peck in 1921 continuing the work of 1919. The surficial Geologic Map includes suggestions made by Frank Leverett in the summer of 1926. R. W. Stone spent a week in the area in October 1926, made most of the photographs used to illustrate the report, wrote additions to the text, and edited the whole atlas. O. A. Ljungstedt, of the U. S. Geological Survey, edited the geologic maps.

The Topographic map, Plate I, made 30 years ago, does not show the Portland cement plants and brick yards built since 1902. Bessemer in particular is inadequately represented. Koppel was added from data furnished by the Koppel Car & Equipment Co., and new streets in Ellwood City from maps by the City Engineer.

SURFACE RELIEF AND DRAINAGE

Drainage.

The region is in the Ohio River basin and is drained by the Beaver River system and Little Beaver Creek. Beaver River is formed by the junction of Mahoning and Shenango rivers one mile below Mahoningtown. (See Plate I).. It meanders over a broad alluvial flat depositing its sediment until Wampum is reached and then travels more directly southward between abrupt walls and without flood plain, finally emptying into the Ohio about four miles south of this region. The total descent of the river in its 22 miles is about 90 feet, of which 50 feet is made in the last five miles. The Beaver River system includes the Mahoning, Shenango, and Connoquenessing with their tributaries; besides the lesser streams which drain an extensive area and empty directly into the Beaver along its course. Nearly three-fourths of the area is drained by this system, while the remainder, in the west and southwest portion, is tributary to Little Beaver Creek, which flows southwestward from the quadrangle, then southeastward, and empties into the Ohio at a place about 8 miles south of the southwest corner of the area.

On the east side of Beaver Valley, Big Run drains a considerable area in the north. It flows through a marshy district known as the Big Meadows but near Joyce tumbles 60 feet over cascades and rapids, and from there flows rapidly into the Shenango. Farther south small patches of country send drainage to the Beaver through McKee Run, Snake Run, and lesser streams, all traversing short ravines with flat, narrow bottoms and steep walls. Connoquenessing Creek enters the region at the east margin and flows northeastward 2 miles to Wurtemberg where it is joined by Slippery Rock Creek. From here its course to the Beaver lies in a westerly winding course between precipitous rock walls. Throughout its course of ten miles within the quadrangle the stream falls more than 100 feet.

The eastern portions of Wayne and North Sewickley townships shed water into the Connoquenessing as does also Franklin Township. A high ridge south of Ellwood City separates the Connoquenessing from the Beaver.

On the west side of Beaver Valley much of the adjoining land is trenched by streams of small size. In the northern area Mahoning River receives the drainage northeast of Mt. Jackson and also that gathered from North Beaver Township by Hickory Run.

The territory in the south and west portions of the region is tributary to Little Beaver Creek. This includes South Beaver, Darlington, and Little Beaver townships, considerable areas of the land immediately east of these and also about one-quarter of North Beaver Township. The surface material of this basin, which is largely sand and gravel, permits rainfall to soak in readily. The minor creeks are dry much of the year and Little Beaver itself is usually very small. It follows a very crooked course, descending about eight feet each mile except below Cannelton where the fall becomes more rapid. Little Beaver Creek flows into Ohio River at Smiths Ferry about 18 miles down stream below Darlington.

Precipitation.

According to data on precipitation[1] in the report of the Water Supply Commission of Pennsylvania, and in Climatological Data by the United States Weather Bureau, the annual precipitation in the New Castle quadrangle is about 36 inches at New Castle, 39 inches at Ellwood City, and 38.5 inches at Beaver Falls. Since 1916 the annual precipitation at New Castle has been about 38 inches. A wide range has been recorded there, the limits being 26.05 inches in 1879, a very dry year and 52.53 inches in 1890. Such marked differences as 40.88 inches in 1919 and 33.02 inches in 1920 are noted.

At Beaver Falls the precipitation from 1909-1915 averaged 38.69 inches yearly, with 11 inches variation, but from 1916-1924 the average was 34.70 and ranged from 43.03 inches in 1921 to 29.91 in 1922.

Surface Relief.

The accompanying topographic map (Plate I) indicates a hilly country partly separated into districts by deep valleys of the Beaver River system and of Little Beaver Creek. A study of the region brings out many elements which enter into its rather complex natural history. From Wampum to Beaver Falls the river is confined between precipitous rock cliffs. At Rock Point it is joined from the eastward by Connoquenessing Creek, itself hemmed in by sheer walls of sandstone. In both cases the gorge is bordered on one or both sides by conspicuous flat rock-cut terraces, 150 feet above the water and locally reaching back a mile to the base of the neighboring hills. North of Moravia there is a terrace 100 feet above the river which is suggestive of the rock shelves down stream. North of Wampum a broad flat is partly the old course of Beaver River and partly rock shelf. Little Beaver Creek, also, though small in volume, occupies a broad valley and meanders over a plain which, at Darlington, is half a mile wide.

Above these alluvial flats and terraces rugged uplands rise to heights of several hundred feet. Slopes are steep; opposite Beaver Falls the terrane rises 530 feet in a quarter of a mile and steep but shorter slopes are found elsewhere in the area. As a rule, the hills rise sharply from the flats and within a mile the difference in altitude is 300 feet. Great numbers of small streams and gullies opening on the lowland reach back into the hills with sharply cut banks and steep gradients. They have eaten the upland away until the divides are small irregular areas or only narrow spurs extending out between adjacent streams. These features of the topography are especially conspicuous in the southern part of the region. The hilltops in all of the townships of the area, except Union, reach more than 500 feet above the river at Beaver Falls or 1200 feet above sea level (See Plate I). A dozen points reach altitudes greater than 1300 feet and a single hill in the southeast corner of Shenango Township stands 1380 feet above sea level. The maximum relief, therefore, exceeds 660 feet. If the valleys could be filled to the level of the upland areas a surface of fairly even sky-line would result. This would be a measure of the clearly recorded work accomplished here by running water and the accompanying agents of rock decay.

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[1] Water Supply Commission of Pennsylvania, Water resources inventory report, Pt. V, Precipitation: Harrisburg 1916.

The surface of a portion of the region has suffered additional alteration; for, as indicated by the map showing the Surficial Geology (Plate II) the area was visited during the Glacial period by at least two advances of the continental ice sheets. The slowly advancing ice eroded the surface of the country, carrying and pushing along and depositing, at various places, the accumulated rock debris. This accumulation of debris and the presence of the great ice sheet in its first advance effectually stopped the northward course of the preglacial drainage and diverted it to the westward. Monongahela, Allegheny, and Beaver rivers, which formerly flowed into the area now occupied by Lake Erie, were turned into the Ohio drainage. Beaver River was reversed, flowing south instead of north. The course of the lower portion of Slippery Rock Creek was changed. When the first ice sheet retreated these rivers developed more direct courses in some places than they formerly had and they entrenched themselves deeply below their former levels. The depths to which they cut their channels in solid rock measure the time that elapsed between the recession of the first ice sheet and the advance of the last or Wisconsin ice sheet. In this later occupancy of this region by a thick mantle of ice, the principal change in the topography was made by the deposition of enormous quantities of sand and gravel, particularly in the main valleys.

The final melting of the glacier left the modified surface practically as it is seen today, and different in many respects from the unglaciated region. Drainage lines were partially blocked or destroyed by the ice and a new system is not yet perfected. This is shown in part by marshes and undrained hollows such as those near Wampum and in Shenango and Slippery Rock townships. The work of the glacier, on the whole, was to erode the upland most and to make the greatest deposition in the valleys, so as to decrease the local relief. The slopes of the region affected are smooth and notably gentler than those of the unglaciated area. Furthermore, the glaciated region is conspicuously strewn with irregular masses and belts of unconsolidated rock debris. These are well developed near Wampum, along the valleys of Little Beaver Creek and Beaver Dam Run, in Shenango and Slippery Rock townships and in many other localities.

Influence of Topography and Situation on Development of Region.

The well-developed stream valleys of this district, by offering easy grades, have favored the construction of railways through this area. The influence of the railroads and of the Pittsburgh and Erie Canal, which followed the valley in the early days, is hardly to be overestimated; for the minerals which stood revealed by the dissection of the hills were thus made marketable. Export of raw materials or their manufacture into finished products has given employment to a large population. Broad terraces and alluvial flats have offered favorable spots for the growth of cities, as at Beaver Falls and Ellwood City. The larger streams provide water supply and power and in part carry off waste products. The Baltimore & Ohio Railroad takes advantage of the flats and terraces of the Connoquenessing in order to reach the Beaver Valley. The Pennsylvania Lines and the Pittsburgh & Lake Erie Railroad obtain low grades along the Big Beaver. The Fort Wayne route makes use of the flats of Little Beaver Creek and then by means of the "Summit Cut" reaches a tributary of the Big Beaver and follows the rock terraces, 150 feet above the water. The bottom land of the Little Beaver gives route also to the Pittsburgh, Lisbon & Western Railroad. In the northeast portion the Buffalo, Rochester & Pittsburgh Railroad follows Big Run to New Castle.

Inasmuch as the topography has exerted its influence upon the systems of transportation within the area, so it has influenced the location of the producing mines of the region. The railroad spurs which have been constructed along Wampum and Thompson runs permitted the ready transportation of coal. The spurs were constructed many years ago with that end in view. The mines which are served by these spurs have been worked for a comparatively long time, and the present working-faces are several thousand feet from the portals. A recently built spur line from the Pittsburgh, Lisbon & Western Railroad tracks at Cannelton southward and southwestward, up a tributary of Painters Run, permits shipment of coal from the area immediately adjacent. In this vicinity a large stripping operation for coal is carried on by the White Clay Mining Company.

The effect of the topography on the locations of settlements and of the connecting roads has been reflected indirectly by the development of mines along the improved roads. Along Bennett Run several coal mines, each producing 100 tons a day, find outlet for their product solely by the use of motor trucks. The same conditions obtain along the Darlington Road (Highway Route 204). To the north of this traffic artery, about a mile east of the Pennsylvania-Ohio State line, a coal-stripping operation has a minimum output of about 100 tons per day. This is handled entirely over the highway, the markets being principally Beaver Falls and East Palestine, Ohio.

GEOLOGY

As knowledge of the general geology of the region is necessary for a clear understanding of its mineral resources, the essential facts are here described.

The phenomena offer for study two main phases of geology: stratigraphy and structure. The former refers to the thickness, character, and relation of the various beds, while the latter deals with the attitudes of the rocks, including problems of folding, dip, etc.

STRATIGRAPHY.

The rocks fall into two main classes, some unconsolidated and others consolidated. Those of the first class were deposited in late geologic time but are nevertheless to be regarded as rocks. The consolidated rocks, which originated in earlier time, include sandstone, limestone, shale, coal, etc., all of which are well exposed in the region. Beginning with the top or youngest beds, the exposed rocks of the area will be briefly described.

UNCONSOLIDATED ROCKS.

QUATERNARY SYSTEM.

The unconsolidated rocks, as shown on the geologic map (Plate II) are of two kinds according to their somewhat different modes of origin at two different periods of time in the earth's history. The youngest consist of stream deposits of gravel, sand, and clay, laid down in the Recent epoch; while the older were deposited in the Pleistocene epoch through the agency of the continental ice sheet or of the water derived from its melting.

Recent Series.

The beds of this epoch consist of gravel, sand, and clay, deposited in times of flood along the valley bottoms by the present streams. These as mapped doubtless conceal, in many places, similar beds of material deposited in like manner by streams or lakes of the preceding or Glacial epoch. The recent sediments are shown on the accompanying map to be a mile wide at the confluence of Mahoning and Shenango rivers, but are absent from the lower course of the Big Beaver. The valleys of Little Beaver Creek and its tributaries also exhibit large low-lying areas covered by deposits of recent age.

Pleistocene Series.

The deposit of this epoch varies widely in composition and form on account of its complex origin. It is of two chief kinds, true drift, laid down by the ice itself, and modified drift which was deposited by streams and lakes arising from the melting of the glacier. Both kinds are characterized by the presence of pebbles or bowlders of granite and other crystalline rocks, which are not native to this region, but have been transported from outcrops in Canada or in the Adirondacks.

Unmodified drift. This deposit occurs alike on hills and in valleys as a mantle of clay, bowlders, sand, and pebbles. It is distinguished by a heterogeneous arrangement of its materials, though it locally exhibits the effects of sorting by water action. The topography or surface aspect also is peculiar, for on much of the upland area it lies as a smooth veneer which imparts gently-rolling slopes. Elsewhere it is piled into irregular short hills which frequently are so grouped as to form undrained depressions among the knobs. Such irregular masses occur on the upland but are more frequently seen along the valleys, where, in some places they comprise terraces. The drift has a known thickness of over 300 feet in a buried valley three miles southwest of Moravia. In general it is thinner on the uplands and especially on the hills of Beaver County south and east of Little Beaver Creek. In that region the drift is commonly so thin as to be easily overlooked, were it not for the presence of granite bowlders of considerable size. Yet its border is readily traceable to within a fraction of a mile. The border of the last or Wisconsin drift, as traced in 1926 by Frank Leverett of the U. S. Geological Survey, is shown on Plate II.

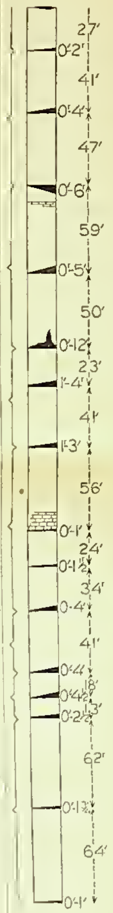
Modified drift. This is a deposit of material washed out from the ice and more or less stratified. For the most part it is composed of gravel, sand, and clay but exceptionally it contains rounded bowlders a foot or more in diameter. The surface of this drift is characteristically smooth and even.

It occurs as terrace deposits along Beaver River, as well shown at Chewton, College Hill, and Beaver Falls, and also in parts of Little Beaver Valley, as below New Galilee at the old railroad gravel pit. In addition it lies as a smooth valley filling more or less hidden by the Recent flood-plain deposits in the valleys of Little Beaver Creek and its tributaries.

The depth of the valley filling as determined by well borings may exceed 100 feet; the terrace beds are also known to be 140 feet thick at Chewton and at least 70 feet in parts of Beaver Falls. Elsewhere along the Big Beaver much of the terrace material occurs as a layer of fine gravel and clay which is only 10 feet in thickness, or even less.

GENERALIZED SECTION OF THE ROCKS EXPOSED IN THE NEW CASTLE QUADRANGLE

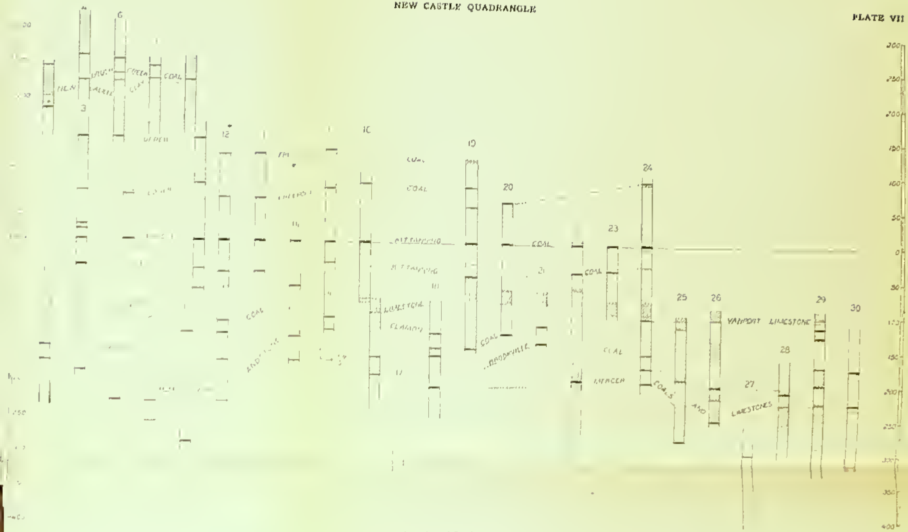
PLATE VI



AGE	SYSTEM	GROUP	SYMBOL	Distance above and below Middle Kittanning coal	MINOR DIVISIONS	CHARACTER AND DISTRIBUTION OF MINOR DIVISIONS	GENERAL CHARACTER OF GROUP
CARBONIFEROUS	PENNSYLVANIAN	CONEMAUGH	Ccm		Shale and sandstone		Shale and sandy shale, which locally becomes sandstone. No persistent strata in upper hundred feet of exposed rocks. No outcrop of Bakerstown coal or Brush Creek limestone which may, however, be present. Massive Buffalo sandstone of Allegheny and Butler counties does not occur here as such. Shales are brown, yellow, red, and green, laminated; commonly fine, but occasionally lumpy. Sandy rocks are generally of medium-sized quartz grains with some brown mica flakes; on the whole, poorly cemented. Beds break down easily into loose sand.
				257'	Thilo coal (local)	Seen only in North Sewickley and Daugherty townships.	
					Shale and sandstone		
				230'	Brush Creek coal	Prevalent. Interval to Upper Freeport coal varies between 65 and 110 feet.	
					Fire clay		
					Shale		
					New Galilee fire clay shale	Yellowish gray; weathers to orange-brown or ocherous color; hard; flinty fracture; excellent marker.	
					Limestone		
					Sandstone and shale		
				189'	East Palestine coal, "Brush Creek"	Valuable in western part; worthless in eastern.	
					Fireclay		
					Limestone	Drab, weathering to buff; composed of 2 layers.	
					Shale and Mahoning sandstone	Massive, thick-bedded; lies upon Upper Freeport coal or separated by 6 feet of dark shale; 10-56 feet thick; occasionally contains pebbles; white or light yellow, weathering to gray and dark brown; forms cliffs; friable, but hardens on exposure.	
					Shale		
		ALLEGHENY	Ca	142'	Upper Freeport coal, "Four-foot," "Six-foot"	May be 6 feet thick, but over much of area it is too thin to be worked.	Prevailing sandstone and shale, with 8 beds of coal, includes nearly all the valuable beds of coal, fireclay and limestone. Total thickness 265-325 feet, averaging 290 feet.
					Fireclay	May be present though coal is absent; pale blue-gray to deep buff; plastic; from few inches to 10 feet thick	
					Limestone	Single layer or two layers separated by shale; drab, weathering to deep yellowish brown; very hard; non-fossiliferous; not noted in Lawrence County portion of area.	
					Shale, 0-75 Butler sandstone, 80-0 Shale with iron carbonate nodules, 0-80	Massive to shaly; frequently cross-bedded; medium fine grain; soft, hardening on exposure; sandstone may be missing and entire horizon filled with shale.	
				83'	Lower Freeport coal, "28-inch," "Bung Eye"	May be absent; roof may be either shale or sandstone; partings not persistent.	
					Fireclay	Gray.	
					Limestone	Not always present blue-gray, weathering to buff. May be two layers separated by shale.	
					Shale, and Freeport sandstone	Lenticular deposition; blue-gray, cream, yellowish brown irregularly bedded.	
				23'	Upper Kittanning coal	Horizon general, but not continuous; usually thin; cannel bed near Cannelton	
					Sandstone and shale	Lenses of sandstone and shale, indicating varied deposition.	
				0'	Middle Kittanning coal	Wide distribution; thickness varies.	
					Fireclay	Blue-gray to buff; soft plastic top, hard blue-gray bottom.	
					Shale with iron carbonate nodules		
				41'	Lower Kittanning coal; "Three-foot"	Widely distributed.	
					Fireclay	Soft plastic gray top; hard blue-gray siliceous bottom.	
					Kittanning sandstone, and shale	Top of sandstone forms cliffs, greenish; platy; interval may be either sandstone or shale	
					Vanport limestone; "Ferriferous limestone"	Lentil; where thin, upper portion of bed seems undeveloped; absent or thin over most of Beaver Co. part of area; characterized by "cone-in-cone" markings; 10-20 feet thick in Lawrence Co. part of area; makes cliffs; weathers in wavy laminations; fossils abundant.	
				97'	Scrubgrass coal	Coal and clay rather persistent in Lawrence Co. part of area.	
					Clay		
					Sandstone, 0-10		
					Shale, 10-45		
					Sandstone, 10-0		
				121'	Clarion coal		
					Fireclay		
					Shale with iron nodules		
				155'	Brookville coal	Thick parting gives name of "twin vein."	
					Fireclay		
		POTTSVILLE	Cpv		Shale		Partly unexposed. Conglomeratic or coarse-grained sandstone, massive and thick-bedded; locally thin-bedded, cross-bedded or shaly; beds show notable changes in character and thickness from place to place. Contains shales, thin coal beds, and thin limestones. Forms cliffs along Beaver River and Connoquenessing Creek. Beds valuable for building-stone; oil-bearing; formerly valuable for iron ore
					Homewood sandstone, and shale	Massive coarse-grained or conglomeratic gray to yellow. Irregular in lithologic character, thickness, and relation to overlying beds. Cliff-maker.	
				196'	**Homewood coal, "Forty-four," "Tionesta"**	Rather persistent; bony, sulphurous; frequent rolls of the roof.	
					Shales with iron carbonate nodules	Iron carbonate nodules formerly of economic importance.	
					Upper Mercer limestone	Hard, dense, fossiliferous, dark-blue; contains nodules of, or may be replaced by, iron carbonate "Mahoning" of Rogers; "Upper Wurtemburg" of Lesley and Lesquereux.	
				214'	Upper Mercer coal	Shaly bed of little character. Underclay is non-plastic and contains abundant remains of **Stigmaria**.	
					Lower Mercer shale	Rich in iron carbonate nodules formerly of economic importance.	
					Lower Mercer limestone	Persistent over large area; lithologically identical with Upper Mercer limestone.	
				227'	Lower Mercer coal	Locally, good block coal. "Lower Potter" of Rogers.	
					Lower Mercer shale	Contains iron carbonate nodules; formerly of economic importance.	
					Upper Connoquenessing sandstone, and shale	White to yellowish brown. Massive; coarse texture; bedding and texture often variable. In places appears continuous with Homewood sandstone; at other places appears continuous with Lower Connoquenessing sandstone.	
				289'	Quakertown coal	Not of minable thickness. Apparently absent in many places although usually fairly persistent	
					Fireclay		
					Shale, with iron carbonate nodules	Characteristically ferruginous, like Mercer shales.	
					Lower Connoquenessing sandstone	Lowest massive bed exposed in this area. Coarse-grained; white to brown; massive or thick-bedded, but may be conglomeratic or shaly.	
					Shale, with iron carbonate nodules	Bluish gray.	
				353'	Sharon coal	Stringers of coal or bituminous shale	
					Sandy shale		
					Concealed		

NEW CASTLE QUADRANGLE

PLATE VII

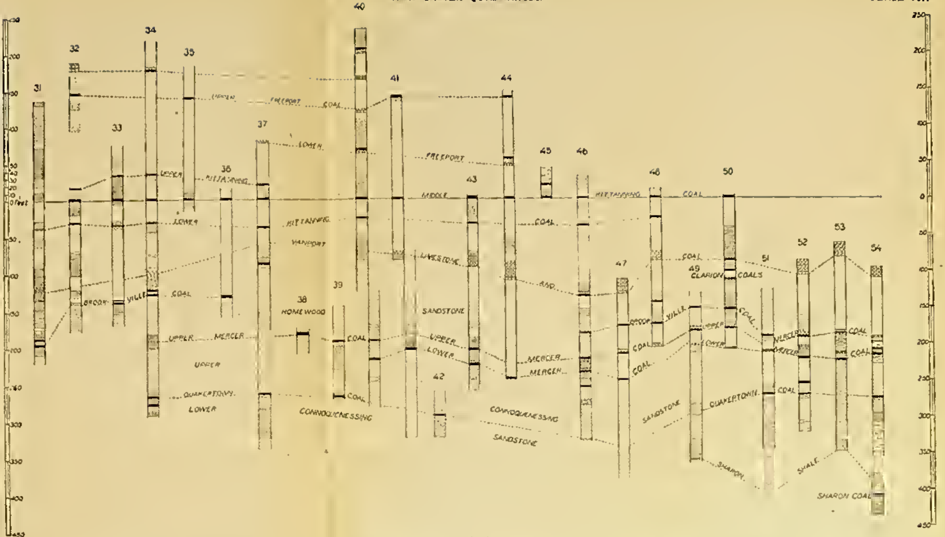


Location of Sections 1-30

1. Beaver Falls, south end
2. Beaver Falls, hilltop ½ mile east of
3. River bluff opposite Beaver Falls
4. Road 1 mile E. of Eastvale
5. Hill ½ mile south of mouth of Bennett Run
6. Opposite P. & L. E. R. R. depot, Beaver Falls
7. Road at head of Bennett Run
8. Northeast of Morado ½ mile
9. Thompson Run
10. Mouth of Thompson Run
11. Road 2 miles E. of Thompson Run mines
12. Bellton
13. Southwest of North Sewickley above mines of Hazen Miller
14. East of Bellton 1 mile
15. East of North Sewickley
16. Ellwood City tunnel
17. Ellwood City, east end
18. Wurtemberg, north of
19. Road east of Squaw Run
20. Ellwood City, north of
21. Mouth of Lone Dell
22. Chewton, 1 mile south of
23. 1½ miles N. of Chewton
24. Schreckert farm, 1 mile N. of Union Valley
25. Ravine between Rigby and New Castle Junction
26. Ravine between Rigby and New Castle Junction
27. East of Rigby
28. Cascades near Joyce, Second Survey report QQ, p. 118
29. Northeast of Mahoningtown behind Lawrence School
30. Road 1 mile E. of Covert

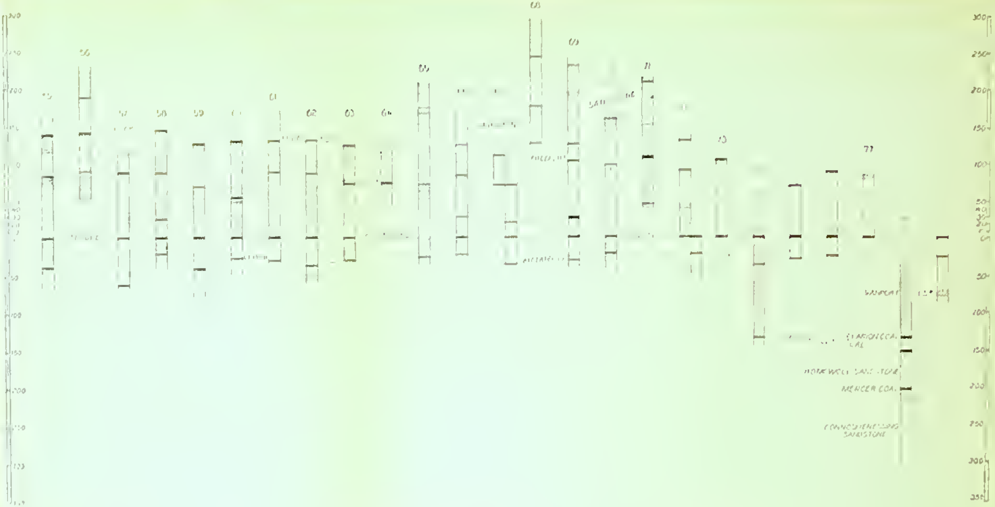
NEW CASTLE QUADRANGLE

PLATE VIII



Location of Sections 31-54

31. Patterson Heights, Beaver Falls
32. South of College Hill, road up ravine
33. South of Morado
34. West of Morado, Bruce farm
35. Morado
36. North of Morado
37. Homewood
38. Northeast of Homewood 1 mile
39. Koppel
40. West of Koppel
41. Possum Hollow, Second Survey Report QQ, p. 230
42. South of Chewton
43. Wampum
44. Wampum
45. Coverdale
46. Edwards Run near Moravia
47. 1 mile N. of Moravia
48. Near school, 1½ miles northwest of Moravia
49. Hickory Run
50. Mount Jackson
51. Southwest of Covert along railroad
52. South of Edinburg
53. Hillsville
54. Quakertown



Location of Sections 55-79

55. Birch Run near State line
56. Birch Run southeast of Cannelton
57. 1 mile southwest of Cannelton
58. 2½ miles southeast of Cannelton
59. Birch Run south of Cannelton
60. Birch Run
61. 1½ miles south of Darlington
62. Darlington
63. 1½ miles E. of Darlington
64. Summit Cut, P., F. W. & C. R. R.
65. New Galilee, at Beaver Clay Mfg. Co. plant
66. East of New Galilee
67. State line N. of Little Beaver Creek
68. J. P. Mansfield land 1 mile W. of Cannelton
69. North of Cannelton
70. Darlington
71. 1 mile N. of Darlington
72. 2 miles E. of Enon Valley
73. Powers Hills farm
74. 2 miles N. E. of Enon Valley
75. McNally place, 1½ miles N. W. of Enon Valley
76. Moravia
77. Honey Creek
78. Forks of Honey Creek
79. Coal test boring, Fullerton farm, 2½ miles N. W. of Mount Jackson, Second Survey Report QQ, p. 134

CONSOLIDATED ROCKS.

This region is a part of the extensive area known to geologists as the Allegheny Plateau. In it the rocks are similar in kind and attitude because they were all deposited in a great inland sea in the same manner and have had similar treatment by natural forces since their origin. The rocks are of four main kinds: sandstone, shale, limestone, and coal. These are consolidated sediments which differ merely because of the varying conditions attending their deposition. Sand resulted in sandstone; mud became shale; coal has originated from the accumulation of vegetable matter in ancient swamps; limestone has in most cases been formed by cementation of shells of marine organisms and by algae and bacteria. Since the rocks occur as a sequence of beds more or less distinct and it is obvious that the lowest beds were deposited before those above, the beds can be separated for convenience of study and description into main and subordinate groups on the basis of time relations. Beds can be distinguished by peculiarities of composition, thickness, color, etc., and frequently by study of the kinds of fossil shells or plants contained in the rocks. In this manner the rocks of the Allegheny Plateau have been divided into systems and these into groups.

In western Pennsylvania rock-groups most completely exposed and best known belong to the Carboniferous Age. For convenience of study this age has been divided into three parts, or systems: the Upper, or Permian; the Middle, or Pennsylvanian; and the Lower, or Mississippian. All of the rocks of the Upper Carboniferous, or Permian, age have been removed by erosion from the area represented by the New Castle quadrangle, as have also the rocks of the upper portion of the Pennsylvanian.

In the area covered by this report the consolidated rocks which are exposed at the surface are of the Pennsylvanian system only. Beds of greater age have been penetrated by drills in search for oil and gas, and they will be described farther on in this report. The bulk of the mineral resources of this area are included in the exposed rocks; hence, a description of these beds follows.

PENNSYLVANIAN SYSTEM.

The Pennsylvanian system of Carboniferous Age has been divided into four parts or groups, named from the top downwards: Monongahela, Conemaugh, Allegheny, and Pottsville. All of the top group of this system and part of the second have been removed by erosion so that the Pennsylvanian is but partly represented in this area. The exposed rocks present, as shown by the generalized columnar section, Plate VI, are approximately 745 feet thick, and are distributed among three groups as follows: Conemaugh 210; Allegheny 290; Pottsville 245.

Conemaugh Group.

Distribution and character. The Conemaugh group or "Lower Barren Measures," extending from the floor of the Pittsburgh coal downward to the top of the Upper Freeport coal, includes about 520 feet of rocks. This thickness has been determined in the Beaver quadrangle, which adjoins the New Castle quadrangle on the south, but in the region under discussion erosion has removed the upper portion of the group. That part remaining is about 210 feet thick. The highest rocks, stratigraphically, are those which are exposed about three-quarters of a mile northwest of the southeast corner of the quadrangle, near the forks of a road. The group underlies the area shown on the map inside or above the outcrop of the Upper Freeport coal. Within Beaver County the Conemaugh is seen in nearly all of the upland area. Lawrence County contains only small isolated patches. These are situated south and west of Wampum, and in the southern portions of Shenango and Slippery Rock townships. A very small area in addition may lie about two miles west of Enon Valley, along the county line.

General section of the lower part of the Conemaugh group.

	Feet
Shale and sandstone	95
Coal thin (local)	..
Shale above, sandstone below	25
Coal (Brush Creek)	0— 2
Fire clay	0— 5
Shale	5—15
New Galilee fire clay shale	5—15
Limestone	0— 1
Sandstone above, shale below	20—30
Coal (East Palestine, "Brush Creek" or "Three-foot")	0— 4
Fire clay	0— 5
Limestone	0— 5
Shale Sandstone, Mahoning	35—55
Shale	0— 6
(Upper Freeport coal)	

Upper beds. The group is composed of beds of shale, and sandy shale which locally becomes sandstone. In the upper hundred feet of exposed rocks no persistent strata appear and no outcrop is seen of the Bakerstown coal or Brush Creek limestone, which, however, may very likely be present, though concealed. The massive Buffalo sandstone of Allegheny and Butler counties does not occur here as such. The shales are of various colors and characters. Shades of brown, yellow, red, and green occur, in frequency about according to the order noted. The lamination is commonly fine but at places the shales are lumpy. The sandy rocks are generally composed of medium-sized quartz grains with some brown mica flakes and are, on the whole, so poorly cemented that the beds break down easily into loose sand.

Below this confusing mass of beds and about 115 feet above the base of the group occurs a thin coal seam. It was seen only in North Sewickley and Daugherty townships. This coal is shown in Section 4 Plate VII, and on the economic geologic map, Plate IV, it is indicated at two neighboring localities along the Daugherty Township line.

The next definite member of the group is a persistent coal (Brush Creek?) which lies from 25 to 30 feet below that last mentioned, and averages 90 feet above the Upper Freeport. This last interval ranges in the area east of the Big Beaver from 65 to 90 feet, and westward from 90 to 110 feet with a possible exception 2¼ miles east of New Galilee where it may perhaps be as little as 65 feet. This coal as seen in North Sewickley Township by I. C. White was identified as the Brush Creek bed of Butler County.[2] Its relations are shown in the sections, Plate VII.

New Galilee clay shale. The New Galilee clay shale lies 10 to 20 feet below the last mentioned coal and 70 to 90 feet above the base of the group. It has a characteristic rusty color of orange brown or ochre, but its hardness and flinty fracture are even more striking. Even when wet it crackles sharply when broken. This bed is named from its occurrence one mile east of New Galilee where it has been prospected on the land of W. H. Anderson (No. 317). The thickness is certainly 12 and perhaps 20 feet. It is a flint fire clay of possible value. When fresh this is a yellowish-gray but weathering produces a much deeper shade of yellow brown. This bed is so readily recognized and so widely distributed that its horizon has been indicated on the geologic map. East of Beaver River the clay occurs on the knob 1½ miles north of Thompson Run mine, and from there to the east and south it is present wherever the hills reach up to its horizon. West of the river it occurs well developed along the hill roads east of New Galilee; in the middle of Chippewa Township; and in South Beaver Township at Saints Rest School. The hills just north and south of Little Beaver Creek show the clay as far west as the State line. It occurs along the road above Cannelton where it is 85 feet above the base of the Conemaugh. The relations of this clay shale are indicated in sections 2, 4, 6, 7 and 11, Plate VII.

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[2] Pennsylvania Second Geological Survey, Rept. Q, p. 208, 1878.

East Palestine coal. This is worked near East Palestine, Ohio (No. 399), by the National Fire Proofing Company and eastward on the high land of Darlington Township by the following: Messrs. Whan (No. 398), McCutcheon (No. 400), Pickles (No. 406), Madden (No. 407), and on the farm of Walters' Heirs (No. 385). Stripping operations are conducted on this bed in Darlington Township by the East Palestine Finance Corporation (No. 490), and in South Beaver Township by the White Clay Mining Company (No. 491*). The thickness of the coal varies from 26 to 47 inches, but full particulars may be found in another place in this report. East of Beaver River this coal occurs as a thin worthless seam 20 feet below the New Galilee clay and 45 feet above the Upper Freeport coal. West of the river the horizon lies 30 to 60 feet below the clay and 40 to 65 feet above the coal. The horizon can usually be identified by a coal blossom or by an underlying bed of limestone which is often present where the coal does not appear. The limestone may be found best exposed above the plant of the Beaver Clay Manufacturing Company, near New Galilee (No. 320), where it occurs above an old sandstone quarry, and separated from the sandstone by 15 feet of shale, as shown by Section 65, plate IX. The limestone is drab, weathering buff, and is composed of two layers which give a combined thickness of 5 feet. Other localities where the limestone is prominently exposed are as follows: Along the ridge road from New Galilee towards West Ellwood Junction, and south from this road to the Fort Wayne Railroad cut; southeast of Darlington 1½ miles along the roads to Morado and to Beaver Falls; and in South Beaver Township one mile north of Saints Rest School.

Mahoning sandstone. The Mahoning sandstone at the base of the Conemaugh group lies either directly upon the Upper Freeport coal or separated from it by as much as six feet of dark shale. It persists through the area as a massive or thick-bedded sandstone about 45 feet thick. The greatest thickness known here, 56 feet, is revealed in Darlington Township by a drill hole of the State Line Coal Company, half a mile north of Mount Nebo School. The least thickness seems to be 10 feet at the head of Bennett Run in North Sewickley Township. Quartz grains of medium to coarse size usually constitute the sandstone but in a very few places white pebbles as large as peas are prominent, as on the farm of Mr. Greeg, one mile east of New Galilee (No. 318). The cementing material is iron oxide. The fresh stone is white or light yellow, but occasionally pink and greenish shades are noticed. Weathered surfaces vary from gray to dark brown. In hardness the stratum is not uniform; for the most part it breaks down under the traffic and forms a sandy road; in a number of places, however, prominent cliffs and upland flats of considerable extent have developed on this bed. Such a cliff 30 feet high is conspicuous at the top of the bluffs which border the river opposite Beaver Falls, and even here the friable nature of the rock is demonstrated by large wind-blown cavities. As a quarry stone it is easily cut into large blocks which slowly harden on the exposed surfaces. This bed has been extensively worked at the following points: Head of Thompson Run (No. 31); east and southeast of New Galilee 1 mile (Nos. 323 and 321); northwest of Cannelton ½ mile (No. 378).

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*Numbers in parentheses refer to locations on the Economic geology map, Plate IV.

Correlation. The identity of the members of the Conemaugh group in this region is of slight economic importance but is of interest from the geologic standpoint. Difficulties in correlation arise from two factors; first, important beds are poorly exposed; second, they probably occur as discontinuous lenses in the group. The exposures are poor because of the thinness of the beds and their position in masses of shale well exposed to the elements. It may be doubted whether the thin coals and limestone of the Conemaugh can ever be traced successfully here, over any considerable area. Obviously such work can only follow from detailed studies extended progressively farther from type localities. In the present work it is thought that two coal beds have been consistently identified in the lower Conemaugh. One overlies the New Galilee clay shale and the other lies below it. The latter bed, called here the East Palestine coal, is known as No. 7 of the Ohio geologists[3] or the Brush Creek coal of the Pennsylvania Survey[4]. It is believed that the true Brush Creek coal, if here at all, is really the upper of the two. The reasons for this view will be briefly stated.

At the type locality along Brush Creek in Butler County, Pennsylvania, the following section was measured by I. C. White:

Section in Butler County[5]

	Feet
Brush Creek limestone	1
Dark shales	10
Brush Creek coal	2½

In that vicinity White reported that the coal lay 70 to 80 feet above the Upper Freeport. At other localities in adjoining regions he tentatively gave the name Brush Creek to coals 50 to 80 feet above the Upper Freeport. In view of present knowledge, it is presumed that the same name has been applied to two or more beds, and that the upper one is probably the true Brush Creek.

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[3] Geological Survey of Ohio, Vol. II, p. 152, 1877.
[4] Pennsylvania Second Geological Survey, Report Q, p 235, 1878.
[5] Op. cit.

The close relation of the East Palestine coal to an underlying limestone has been noted in the present report. White[6] also thought the horizons practically identical. The interval above the Upper Freeport ranges from 35 to 65 feet and is generally 50 feet. This limestone is traced southward from Saints Rest School by L. H. Woolsey[7] and is described for that region as a lentil about 30 feet above the Upper Freeport. He also describes a section of the Brush Creek limestone and coal almost identical with that measured by White and states that this coal varies in position from 75 to 110 feet above the Upper Freeport and averages 95 feet. This seems to demonstrate that the Brush Creek coal lies about 65 feet above the limestone lentil of the East Palestine horizon.

The relation of the two coals is perhaps further indicated by a comparison of section 11, Plate VII with the notes which White made at the same locality[8]. He describes the Brush Creek coal as 85 feet above the Upper Freeport which, if measurements were correct, places it 30 feet above the coal of section 11 and also above the New Galilee clay. At the State line, therefore, in section 56, Plate IX, the probable position of the Brush Creek coal is still above that clay or 60 feet above the East Palestine coal.

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[6] Op. cit.
[7] Woolsey, L. H., U. S. Geological Survey Geological Atlas, Beaver folio (No. 134), p. 6, 1905.
[8] Pennsylvania Second Geological Survey, Report Q, p. 208, 1874.

Allegheny Group.

General section of the Allegheny group.

		Feet	Average feet
Coal, (Upper Freeport, "Four-foot," "Six-foot" at Wampum, "No. 6")		0- 6	130
Fire clay		0-10	
Limestone		0- 6	
Shale	0-75	30-75	
Sandstone (Butler)	80- 0		
Shale with iron nodules	0-80		
Coal, (Lower Freeport, "28-inch", "Bung Eye", "Six-foot" at Mountair, "No. 5")		0- 5	
Fire clay		0- 3	
Limestone		0- 3	
Shale		30-75	
Sandstone (Freeport)			
Coal, (Upper Kittanning, "Darlington" at Cannelton)		0-12	
Sandstone above, shale below		10-40	
Coal, (Middle Kittanning, "Darlington" or "Three-foot" in much of Beaver & Lawrence Counties, "18-inch", No. 3 a)		1- 4	160
Fire clay		1-10	
Shale with iron nodules		20-50	
Coal, (Lower Kittanning, "Three-foot" at Beaver Falls; "18-inch" at Wampum, "No. 3")		1- 3	
Fire clay		4-10	
Shale		20-85	
Sandstone (Kittanning)			
Limestone, (Vanport, "Ferriferous")		0-20	
Shale		0- 1	
Coal, Scrubgrass		0- 1	
Clay, Scrubgrass		0- 1	
Sandstone	0-10	20-45	
Shale	10-45		
Sandstone	10- 0		
Coal, Clarion		0- 1½	
Fire clay		0- 5	
Shale with iron nodules		15-45	
Coal, Brookville		0- 4	
Fire clay		0- 3	
Shale		0-25	
(Homewood sandstone)			

Distribution and character. The rocks extending from the top of the Upper Freeport coal down to the top of the Pottsville (Homewood) sandstone are known collectively as the Allegheny group because of the good exposures and early study of these beds along Allegheny River. An earlier and synonymous name is Lower Productive Coal Measures. Within this area the group is from 265 to 325 feet thick, averaging 290 feet. It includes nearly all of the valuable beds of coal, fire clay, and limestone of this region.

Except where the Conemaugh group caps the hills of the southern part of the region, the Allegheny group underlies most of the surface. At Beaver Falls it extends from river level nearly to the tops of the cliffs; and is found back from the river along the tributaries. The slight folding of the rocks carries the base of the formation from an elevation of 720 feet at Beaver Falls to 885 at Wampum and about 1000 at New Castle Junction. The bottom beds are not exposed along the valley of Little Beaver Creek.

The columnar section exhibits a compiled average section of the group. It shows prevailing sandstone and shale with eight beds of coal.

Upper Freeport coal. The Upper Freeport coal is known under several local names. Along the State line it is Coal No. 6 of the Ohio geologists. In the vicinity of Wampum it is called the Six-foot. Over most of the region the name Four-foot is widely used.

The position of the coal is shown on the geologic map at the top of the Allegheny group. In Beaver County its horizon is generally below the hilltops and may be followed as a sinuous line fringing stream courses, but in Lawrence County the coal is less widely distributed. It occurs, however, two miles east of Enon Valley, (section 72, plate IX), and doubtfully two miles west (No. 415). It lies in the hilltops west and south of Wampum but probably does not occur in North Beaver Township. The coal has been seen two miles southeast of Union Valley in Shenango Township, and north of No. 135. In several other areas near by the Upper Freeport coal may be concealed or its position occupied by glacial drift. The coal has an undulating position, which in general becomes higher to the north; the full statement of the dip of the rocks in this region is given under "Structure." The coal has its lowest elevation at Beaver Falls where it is 230 feet above the river or 960 feet above sea level. At the head of Thompson Run the same coal has risen to 1160 feet and where it was observed in Shenango Township, as mentioned, the elevation is 1295. In the southwest area, near Elders Woolen Mill (section 57, plate IX), this coal lies at an elevation of 1020 feet. From here it rises both to the southeast and the northeast and reaches 1160 feet in the center of Chippewa Township and 1150 near Enon. In the hill 1½ mile northwest of Morado (No. 288), the coal was once opened along the road 1190 feet above sea level. At Wampum it ranges from 1140 to 1160 feet above sea level.

The coal ranges in thickness up to six feet and over much of the area it is too thin to be worked. At the working mines it averages between 32 and 50 inches, but in places nearly or entirely pinches out suddenly. In such places the overlying shale is usually absent and the Mahoning sandstone lies on the coal, commonly with stringers of bituminous matter occurring in the lower layer of the sandstone.

This condition probably means that currents eroded the roof shale and coal to a greater or less degree; after which the sand was deposited on the irregularly eroded surface. On the other hand the absence of a normal thickness of coal may be due to unequal deposition in the ancient swamps, caused by uneven floor. Although the Upper Freeport is noted for irregularity in thickness and quality, the uniformity of conditions accompanying the deposition in local areas is attested by the similarity of the partings or bands which separate the coal into benches. One of these, about an inch thick, seems to occur commonly near the base of the coal, varying, however, in height from 2 to 12 inches. Impurities of sulphur and dirt occasionally are notable in this band and the underlying coal.

Upper Freeport fire clay and limestone. The Upper Freeport fire clay occurs immediately below the Upper Freport coal and is present in some places even where the coal does not appear. It ranges in thickness from a few inches to 10 feet, but wherever well exposed is from 1 to 3 feet thick. Eight to 10 feet is reported[9] from the vicinity of the Summit Cut of the Pittsburgh, Fort Wayne & Chicago Railway, (section 64, Plate IX), where it was once worked into fire brick. The clay is plastic and is usually stained by disseminated iron to a deep-buff color, though occasionally the color is pale blue-gray.

The Upper Freeport limestone is beneath the clay just described. The bed is from 1 to 6 feet thick and is either a single layer or two layers separated by shale. The fresh stone is drab or light brown but it weathers to a deep yellow brown. It is very hard and is non-fossiliferous but exhibits at the surface irregular bodies as much as one inch in cross section as though composed in part of fragmental materials.

The limestone was seen at about one-half of the exposures of the coal and at one-third of all exposures of the limestone horizon, and is especially persistent in Big Beaver Township, Beaver County. It was not noted in Lawrence County. It may be seen along the ridge road south from Ellwood City, and 6 feet thick at Chas. Herman's coal bank (No. 32), 1½ miles east of Thompson Run mine. It lies as bowlders at the top of the Summit railroad cut and is seen below the Upper Feeport coal at the country banks two miles southeast of Darlington.

Butler sandstone. The Butler sandstone occupies part or all of an interval of 30 to 75 feet between the Upper Freeport limestone and the Lower Freeport coal. This prominent sandstone bed was named from the typical exposure near the town of Butler[10]. In general character it resembles the Mahoning sandstone. It may be massive or shaly and frequently it exhibits cross or irregular bedding. Some of the stone can be used for building. At Boyer's quarry (No. 242), on the west outskirts of Beaver Falls, the Butler sandstone occurs in beds from 1 to 5 feet thick, prevailingly yellowish white, but locally varying to brown. It has a grain of medium fineness. Although somewhat soft when freshly quarried it hardens after exposure.

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[9] Pennsylvania Second Geological Survey, Rept. Q, p. 46.
[10] Pennsylvania Second Geol. Survey, Vol. Q, p. 47.

The observed interval between the Upper and Lower Freeport coals ranges from 35 to 80 feet but more often is between 40 and 60 feet. The top of the interval in three-quarters of the exposures is filled with shale or sandy shale, but it is occupied by sandstone 20 to 30 feet thick where exposed in South Beaver Township. A 20 foot sandstone in the middle of the interval in the area north of Little Beaver Creek along the State line, is separated from the Upper Freeport coal by 15 feet of shale and from the Lower Freeport coal by 20 feet of shale. The bottom of the interval is sandstone in one-half the exposed sections. This condition may be seen at Wampum, near Belton, and along Bennett Run. Opposite the P. & L. E. depot at Beaver Falls a 45 foot sandstone cliff stands directly above the Lower Freeport coal (section No. 6, plate VII). Massive sandstone occasionally fills all the space between the coals or in the absence of the Lower Freeport coal even extends below this horizon. This condition was observed in ravines below Patterson Height and just beyond the southern margin of this area (section 31, plate VIII). Again, the sandstone may be missing and the entire interval filled with shale. A group of sections beginning at Stockman Run near West Ellwood Junction and extending due southwest past the Summit Cut into Chippewa and South Beaver townships, exhibits shale 40 to 50 feet thick. This shale frequently bears small iron nodules in considerable number which range through a zone from 2 to 25 feet thick and vary in vertical position. Thus in South Beaver and Darlington townships they occur immediately above the Lower Freeport coal. Along Jordan Run they lie 10 feet higher and at Stockman Run they lie 30 feet above the coal. In general where the interval between the coals is greatest a considerable thickness of sandstone occurs; and where it is smallest, so far as seen, shale prevails.

Lower Freeport coal. The Lower Freeport coal is usually 40 to 60 feet below the Upper Freeport but it may be absent altogether. In one-half the exposures it occurs immediately beneath the Butler sandstone and in the others has a shale roof. Like the Upper Freeport coal it also is frequently underlain by fire clay and limestone. In the western part of the area this bed is known as Coal No. 5. East of New Galilee where mined (No. 323), it is the 28-inch or Bung Eye, and at Mountair it is known as the Six-foot. It underlies the same areas as the Upper Freeport coal, but from its lower position in the hills extends farther in all directions. Its actual horizon where known is shown on the map. In Beaver County the coal is clearly present on both sides of the river, but in Lawrence County the thick covering of glacial drift generally conceals this horizon. The coal is known, however, in the hills west of the river as far north as Moravia and east of the river it doubtless occurs in many of the hills north of Wayne Township. It was formerly opened on the land of Mr. Schweikert (section 24, plate VII), just north of Union Valley, and occurs also 5 miles east of New Castle near the northwest corner of Slippery Rock Township (No. 175).

The thickness of the coal ranges up to 65 inches. At Mountair where mined it is 40 to 55 inches thick. Near Darlington, Enon Valley, and New Galilee it averages about 28 inches. It is reduced to 10 inches along Bennett Run and is only 19 inches thick in the cliffs opposite Beaver Falls. Doubtless the coal is absent from much of the area because of erosion by currents which deposited the Butler sandstone, but inequality of original deposition seems responsible for much of the irregularity in thickness, since the exposed coal, where thin, is as likely to have a roof of shale as of sandstone. Thus at Summit Cut and Stockman Run the roof is shale; at Bennett Run and at Beaver Falls it is sandstone.

The benches and partings of the coal bed are not persistent far in in any direction; the coal may be clean or broken by thin bands of shale at neighboring localities. These bands in the coal are usually less than one inch thick.

Lower Freeport fire clay and limestone. The Lower Freeport fire clay immediately below the coal is 1 to 3 feet thick and gray in color. At Summit Cut it is in beds of 1 and 3 feet with two layers of limestone (section 64, plate IX). It occurs similarly near the Beaver Clay Manufacturing Company plant near New Galilee (No. 320).

The Lower Freeport limestone frequently occurs below the fire clay but it is not always present. Thus, although the horizon was observed at about 70 localities, the coal was noted probably 50 times without the limestone and only 15 time with it. In five places the limestone was observed apparently without the coal This limestone greatly resembles that under the Upper Freeport coal in thickness, color, hardness, and surface features. No shells have been observed in it but nodular fragments are common. The usual blue-gray color gives place to buff or deep yellow on weathering. The rock is usually in one layer 12 inches or more in thickness, but in Stockman Run and at the Summit Cut it is in two layers separated by clay shale. There the top bed measures 12 inches and the lower bed 2 feet. The limestone is perhaps best exposed at the places mentioned, but other localities may be noted by reference to the map as follows:

Along Bennett Run just east of the school house (No. 14).

Along the road southwest from North Sewickley above the mines of Hazen Miller and others (section 13, plate VII).

In South Beaver Township in the road above Watt's mill and in the ravine above Elder's mill (sections 57 and 56, plate IX).

In Little Beaver Township one mile from the east line at the hilltop between Beaverdam Run and Little Beaver Creek (section 73, plate IX).

In North Beaver Township 1½ miles northwest from Mountair above house of T. W. Swisher (No. 439), also 1½ miles farther west near the road forks (section 77, plate IX).

Between Wampum and Coverdale on the north slope of the hill at an old coal opening (No. 347).

Freeport sandstone. The Freeport sandstone, below the coal and limestone last described, is not a persistent bed in this area but represents lenticular deposition in basins more or less detached. Locally the sandstone may extend 30 to 75 feet downward to the horizon of the Upper Kittanning coal or even lower, or this interval may be occupied by shale. The sandstone is hard, of medium grain, and irregularly bedded. It is frequently blue-gray to cream in color, although more often yellowish brown.

In Beaver County it is best exposed in Darlington and South Beaver townships, where it may be seen 60 feet thick above the cannel coal at Cannelton, and along the roads leading to the hills from Little Beaver Creek and from Brush Run. Along the road from Enon to Darlington in the vicinity of Madden Run this sandstone is blue-gray, thinly laminated, and 40 feet thick. There a thin coal (possibly the Upper Kittanning) occurs in the basal layers of the sandstone. The stone has been quarried for local use near the head of Madden Run (No. 409), where a ledge 20 feet thick is exposed. Along Beaver River this sandstone is not strongly developed in the quadrangle but it thickens to the southward.

In Lawrence County the best exposures of the sandstone are in the roads of Little Beaver Township. One mile from the east line of the township, in the hill between Beaverdam Run and Little Beaver Creek, this sandstone is light gray, thin bedded, 60 feet thick, and is both softer and coarser than where observed elsewhere.

Upper Kittanning coal. The Upper Kittanning coal is a thin bed about 50 feet below the Lower Freeport coal but in extreme instances the interval may be as little as 30 feet or as much as 75 feet. Of the seventeen localities where this bed was observed one was at Coverdale, Lawrence County, and all the others in Beaver County, where it was found in all townships but Chippewa. Although coal occurs rather generally at this horizon it probably was deposited in somewhat local areas and is not continuous. Thus, at Coverdale it is 26 inches thick in an old railroad cut (section 45, plate VIII), but drill holes and shafts short distances to the east and south failed to find this bed. The coal is usually too thin to be of value. Opposite Beaver Falls it occurs 50 feet below the Lower Freeport in two beds of 4 inches and 12 inches separated by 5 feet of shale (section 3, plate VII). It may be seen also above the Middle Kittanning coal openings at Eastvale (No. 8), and Homewood (No. 305), and both south and west of Morado (sections 33 and 34, plate VIII). In these exposures the coal is from 17 to 12 inches thick.

The Upper Kittanning coal has a remarkable development at Cannelton on the land of I. F. Mansfield where bituminous coal is overlain by cannel coal ranging up to 12 feet in thickness.

Extensive mining and prospecting has shown that the coal is restricted to an oval area, or apparent channel, whose length and width are 2 to 3½ miles and 600 feet to 1 mile, respectively. The longer axis extends northwestward from Cannelton. The central portion of the oval is practically barren and the coal lies around its margin as a continuous basin or trough only a few hundred feet wide. This occurrence suggests that the coal-forming materials were laid down in a great lagoon or ox-bow. Measurements of the coal follow:

Section of Upper Kittanning coal at Cannelton

	Feet
Sandstone	
Cannel slate	0— 6
Cannel coal	0—12
Bituminous coal	0— 3½
Maximum thickness in any one section	15

The cannel coal is 8 or 9 feet thick in the middle of the basin but rapidly thins toward the margins as the roof and floor approach each other. The bituminous coal averages from 6 to 12 inches but becomes twice as thick around the margin where it is banded with impurities. Locally where the cannel is thin this lower coal thickens to 3 or 3½ feet. The name Darlington was given to this bed by I. C. White,[11] but was more widely extended by him to the Middle Kittanning. For this and other reasons the name Darlington is not continued in this report.

An interval of 10 - 40 feet separates the Upper Kittanning coal from the coal next lower. This distance as measured in seventeen places averages 27 feet. Where this part of the geologic column is well exposed the space is occupied by sandstone or by shale or by both. These beds appear to be in lenses and seem to indicate that deposition at that time varied in character vertically and horizontally even within short distances.

Middle Kittanning coal. The Middle Kittanning coal, so frequently called the Darlington bed by I. C. White, lies about 27 feet below the Upper Kittanning. The average interval between the

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[11] Pennsylvania Second Geol. Survey, Vol. Q, p. 51.

Lower Freeport coal and the Middle Kittanning coal in 49 measured sections was 77 feet, though this interval may range from 50 to 110 feet. The distance from this bed to the Upper Freeport as noted in 43 places ranges from 110 to 160 feet but maintains a fair average of 130 feet.

The bed has a wide distribution and is opened at many places. It is near the bottom of the hills along the valley of the Little Beaver system but about 250 feet above water level at Beaver Falls and still higher in much of the quadrangle. The coal rises to an altitude of 1150 above sea level in the northern portion of the region and occurs only in the tops of the hills. The horizon is above the surface in much of North Beaver, Shenango, and Slippery Rock townships, hence the coal has been eroded from these localities. It is entirely gone from Union, Taylor, and Mahoning townships, within this quadrangle. Its position and presence in considerable portions of Lawrence County is rendered doubtful by the thick covering of drift.

The coal bed varies considerably in thickness and structure but is always found where exposures are good and is of reasonably uniform character within local areas. Measurements of thicknesses show a range of 12 - 44 inches. In the southwestern townships the coal is present but is generally thin. It is also uniformly thin between Beaver Falls and Morado, but north from that place and in the area across the river to the east it is much thicker. At Beaver Falls, Darlington and other places this bed is frequently called the 18-inch coal. Where its thickness warrants the name it is called the 3-foot and is mined, as at Possum Hollow, Wampum and in parts of Lawrence County.

The presence and position of partings or bands in this coal is frequently constant over a considerable area, but no such marking can be said to be characteristic of the bed throughout the region. It frequently measured 12 to 26 inches of clean coal; more often perhaps a single clay or shale parting of an inch or less occurs near the base of the bed and divides it into two benches. The upper one ranges from 18 to 28 inches thick, and the lower one 3 to 7 inches. In other localities an additional band is present which divides the upper bench of coal into a top portion measuring 7 to 12 inches thick and a lower portion 8 to 16 inches. In a number of places a notable parting of shale or sandstone measures 4 to 12 inches thick. This is reported to thicken to 2 feet in Stockman Run. The position of this band suggests that it represents a thickening of the upper parting so frequently noted in the coal.

Middle Kittanning fire clay. The Middle Kittanning fire clay occurs immediately beneath the coal. It is usually reported to measure 1 to 4 feet thick, but is said to reach a thickness of 10 feet in a few places. The top part is blue-gray to buff in color and soft and plastic. At varying distances below the top this becomes a hard blue-gray clay or clay-shale, which may contain nodular balls of iron carbonate and pyrite. In a few places non-plastic flint clay occurs with the plastic variety.

Beneath the fire clay, and between it and the next underlying coal, is an interval usually filled with shale. This interval ranges between 20 and 50 feet but in 73 measurements averages 35 feet, with variation of only 10 feet either way. The rocks of this interval were seen well exposed in a few places only and this is interpreted to mean that the beds probably are shale. Nodules of iron carbonate are characteristically imbedded in this shale, as noted in over a dozen widely scattered localities.

Lower Kittanning coal. The Lower Kittanning coal lies 20 to 55 feet below the Middle Kittanning; 85 to 130 feet below the Lower Freeport, and 140 to 180 feet below the Upper Freeport. The average intervals follow:

Distance below Middle Kittanning coal, 73 measurements, 35 feet.
Distance below Lower Freeport coal, 33 measurements, 110 feet.
Distance below Upper Freeport coal, 29 measurements, 163 feet.

The extent of this coal is practically the same as that of the Middle Kittanning but because of its lower position in the hills it underlies a slightly larger area. It is the horizon frequently opened along Beaver River and Little Beaver Creek for coal and fire clay. On the map the position of this coal is shown in all the townships of Beaver County and in those of Lawrence County excepting Mahoning, Union, Slippery Rock and Perry. In Lawrence County the Lower Kittanning coal is thin and is not well known.

More than 40 careful measurements were made of this coal. It ranges in thickness from 12 to 36 inches and averages about 24. The coal may be perfectly clean from top to bottom but more often it is interrupted by a shale parting 7 - 12 inches below the top. Occasionally two partings are present, the second occurring about 6 inches above the floor of the coal. Other partings were noted also but none of these is persistent over a large area.

Lower Kittanning fire clay. The Lower Kittanning fire clay, as shown by the map, underlies a large area. It lies immediately beneath the coal. Since outcrops of clay seldom give an accurate idea of the thickness of the bed, reliable figures are obtainable only where the clay has been exploited or where it has been exposed in the drainage ditches of coal mines. Thickness of this clay at about two dozen localities was either observed by the writer or reported by reliable miners. It is characterized by a remarkable thickness of 4 - 8 feet and occasionally 10 feet. The bed often shows 4 - 5 feet of soft, plastic, gray clay which is underlain by 5 feet or more of hard, blue-gray siliceous clay or clay-shale, commonly called "silica rock." Below is sandstone. The soft top clay may be absent or thin, as in the coal mine of Addison Davidson (No. 237) at Beaver Falls. Balls of iron carbonate occur in the clay and cause reddish discoloration. These seem to lie most frequently in the hard clay.

Kittanning sandstone. Beneath the fire clay last described occurs an interval of 20 - 85 feet variously filled with sandstone and shale but frequently showing at the top a light gray sandstone which weathers into cliffs 10 feet or more in height. This sandstone splits into thin beds or plates. It has a fine to medium grain and frequently a greenish color. The sandstone may be absent and the interval filled with shale, or the sandstone may thicken and occupy much of the interval. In the ravines south of Beaver Falls along the river this sandstone is as much as 45 feet thick. It may be seen opposite the lower part of town at the top of the river cliff and beneath an extensive flat terrace. Within the quadrangle it has not been noted well developed in Lawrence County though met often in Beaver County. This is probably the bed exposed along the upper course of Brush Run, and again as a cliff at the railroad cut 1½ mile below Cannelton. It was once quarried on the land of George Greer, 1¼ miles north of New Galilee where it is 20 feet thick.

Vanport limestone. The Vanport or Ferriferous limestone occurs as a lentil ranging from 0 to 20 feet in thickness. Where thin the upper portion of the bed appears to be undeveloped since in such cases the interval from the limestone to the overlying coals is much greater than usual. The distance to the Lower Kittanning coal ranges from 20 to 85 feet but an average distance determined from 30 measurements, is about 50 feet. The interval from the limestone to the Middle Kittanning coal averages 75 feet where the limestone is thick, as measured in 37 places, and 105 feet where the bed is thin, as determined in 11 localities.

The limestone is absent or very thin over all of the Beaver County part of this area except the portion south and southeast from Ellwood City to Belton and North Sewickley. Where thin, it is a compact layer of one foot or less, with blue-gray color when fresh but weathering to buff. It is especially characterized by peculiar "cone-in-cone" markings which have not been reported in any other limestone of this region. Where fully developed as seen over much of Lawrence County east of Beaver River, and at Wampum, Bessemer, and north of Moravia, it ranges from 18 to 20 feet in thickness and has a strikingly characteristic appearance. It makes cliffs along the hills and large masses of the rock break away and strew the lower surface.

The rock weathers in wavy laminations an inch or more in thickness which impart a shriveled aspect to the edges of the beds. This feature is very characteristic. Fossils are very abundant on the surface and serve to help identify the bed. In its thick development the limestone shows a prominent division on the basis of color into two benches. The top four-fifths is gray and the basal layer is dark blue-gray.

The outcrops of the thick limestone are well known. The thin limestone may be seen in many places:

In Trough Run and along the cliff east of Beaver Falls, and in the ravines to the south.

Near the head of Edwards Run, one mile west of Moravia (No. 452).

Below Mt. Jackson on the west hillslope (No. 460).

East of New Castle Junction at head of north facing ravine, section 25, plate VII.

Above Mahoningtown, section 29, Plate VII, at head of ravine behind Lawrence School.

Exposures of calcareous character thought to represent the Vanport were observed along Possom Hollow road (No. 333), and along Wallace Run half a mile west of Morado (No. 286).

At Stockman Run (No. 312), the Vanport is possibly present, 1 foot thick, 18 feet below the Lower Kittanning coal.*

Scrubgrass coal and clay. The Scrubgrass coal and clay, which are separated from the Vanport limestone by a few feet of shale, seem to persist over much of the Lawrence County area where this horizon is exposed. The coal is frequently reported by the quarrymen to occur immediately below the Vanport limestone. At the No. 2 quarry of the New Castle Portland Cement Company (No. 190), it may be seen 14 inches thick separated from the limestone by 12 inches of black shale and underlain by about 8 feet of fire clay and shale. It occurs on Edwards Run (No. 452), and below Mt. Jackson immediately below the thin limestone with its cone-in-cone structure, (No. 460). The blossom of this coal is seen beneath the limestone along Snake, McKee, and Duck runs and is prominent along the road from Wurtemberg to North Sewickley, where it lies above a bed of blue-gray sandstone, thinly laminated. It is seen in a similar relation two miles east of Thompson Run mines at the base of the hill, over 10 feet of thin white sandstone (section 11, plate VII), and at Thompson where the same sandstone is quarried. This remarkably striking bed of white or blue-gray sandstone is very persistent below the Vanport and may be the Clarion sandstone.

Clarion coal. The Clarion coal lies 20 - 45 feet below the base of the Vanport limestone and, where the interval could be measured, 90 to 150 feet below the Middle Kittanning coal. It has been observed from a few inches to 18 inches thick. It can be seen in the cliffs east of Beaver Falls about 50 feet above the river and rising to the north. At Homewood the coal is 30 feet above the railroad track; 90 feet below the Middle Kittanning. It is separated from the white shaly sandstone above it by 20 feet of brown shale. On the east side of Beaver River a coal is seen at the same horizon between Bennett and Thompson runs. It occurs also along the Connoquenessing in North Sewickley and Franklin townships about 30 feet below the base of the Vanport limestone, or 140 feet below the Middle Kittanning coal. At the mouth of Brush Creek, just east of the boundary of this area the Clarion coal 1½ feet thick occurs at water level. The coal is thought to be 20 feet below the Vanport limestone at Mt. Jackson, and just above Mahoningtown.

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*Pennsylvania Second Geol. Survey, Report V. p. 193.

Below the Clarion coal occurs 5 feet of sandy fire clay and an interval of 15 to 40 feet which usually seems occupied by dark shale commonly containing nodules of iron carbonate.

Brookville coal. The Brookville coal occurs 35 - 85 feet below the base of the Vanport limestone and near Beaver Falls is usually separated from the Pottsville sandstone by 10 feet of fire clay and sandy shale. It is reported as 3 feet thick below New Brighton at the mouth of Blockhouse Run[12]. It is characterized by a thick parting of shale which gives rise locally to its name "the twin vein." It has this structure in Harbison Hollow, just west of College Hill (No. 246); along Wallace Run, one mile west of Morado (No. 286); in the first hollow north of Morado on Benjamin Grim's place (No. 284); and is reported one mile north of Union Valley 50 feet below the base of the Vanport limestone and separated into benches of 12 inches and 20 inches by 6 - 12 inches of shale. At Homewood and at Thompson Run the horizon of this coal is occupied by sandstone. The Brookville seems to be present one mile north of Moravia where it is 19 inches thick, and 20 feet above the Homewood sandstone at Mr. Brest's (No. 455). There a sandstone forms the roof. Below Mt. Jackson this coal is thought to be the one 35 feet below the Vanport limestone, and above Mahoningtown it is about the same position. Along the Connoquenessing southeast of North Sewickley this coal is separated from the Clarion by 20 feet of brown shale.

Plate VI shows the ranges and the averages of intervals between the foregoing coal beds of the Allegheny group. Although the measurements indicated apply particularly to the southeastern portion of the quadrangle, the figures will be found essentially correct for the entire area.

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[12] Pennsylvania Second Geol. Survey, Vol. Q, p. 63, 1878.

Pottsville series.

General statement. The Pottsville series which underlies the Allegheny, usually begins a few feet below the Brookville coal, but in some place seems to reach upward into the position usually occupied by Allegheny beds. The exposed thickness of the Pottsville in this area, compiled from outcrops where the several members appear to have their average development, is about 195 feet. The unexposed thickness is 70 feet. Observations of the thickness of unexposed rocks of Pottsville age is taken up in the later discussion of oil wells; and relations of the members is shown by logs of wells on plate X.

Average section of Pottsville Series.

	Feet	Average feet
Homewood sandstone	20 - 60	40
Shale		
Homewood coal, "Four-foot", "Tionesta"	0 - 4	
Homewood shales with iron carbonate nodules	0 - 30	
Upper Mercer limestone	0 - 4	25
Upper Mercer coal	0 - 4½	
Upper Mercer shale	10 - 25	
Lower Mercer limestone	0 - 3	
Lower Mercer coal	0 - 2½	
Lower Mercer shale	5 - 45	
Upper Connoquenessing sandstone	40 - 84	110
Shale		
Quakertown coal	0 - 1¾	
Fire clay		
Shale with iron carbonate nodules	1 - 60	
Lower Connoquenessing sandstone	20 -100	
Shale with iron carbonate nodules	10 - 20	
Sharon coal	0 - 1	
Sandy shale	20	
Concealed (Pottsville)	50	

The series consists for the most part of sandstones, notably massive and thick-bedded, but also locally thin-bedded, cross-bedded or shaly. It is conglomeratic or coarse-grained as a rule. Although shale and thin coals and limestones occur in the series, they hardly detract from its general massive aspect. These rocks, as shown on the geologic and economic maps, Plates III and IV, crop out from Beaver Falls northward, forming the steep cliffs confining Beaver River and Connoquenessing Creek; and farther north where drift mantles the surface they are still exposed in occasional ravines along Mahoning and Shenango rivers. Here the top of the Pottsville exposures is nearly 300 feet higher than at Beaver Falls. This group is interesting from an economic standpoint, inasmuch as the Pottsville contains the beds which at the surface are so extensively quarried for building stone; and other beds which, in places, are oil-bearing. It was formerly valuable for its iron ore, and, to a slight degree, for coal.

This series was correlated by I. C. White with the Pottsville formation in the anthracite fields, so named by J. P. Lesley from its development near Pottsville, Pennsylvania. It is thought to be equivalent to the Seral conglomerate of Rogers.

Description. On the basis of lithologic character, the series was divided by I. C. White into the following subdivisions or members:[13]

Homewood sandstone
Homewood coal and shales
Mercer coals, limestones and shales
Upper Connoquenessing sandstone
Quakertown coal and shales
Lower Connoquenessing sandstone
Sharon coal and shales
Sharon conglomerate

As shown by the accompanying sections, three thick sandstones are separated by beds of shale, coal, and limestone. All of these members are well exposed within the quadrangle and its marginal areas, though they do not all occur in any one vertical section. The Sharon conglomerate was not observed but is described on a following page. The beds exhibit notable changes in character and thickness from place to place, yet persist to a remarkable degree within the quadrangle and over much of the Appalachian Basin.

Homewood sandstone. The Homewood sandstone, known to drillers as the "Forty-foot," is the top member of the Pottsville series, and is usually a massive, coarse-grained or conglomeratic bed of gray to yellow color, which measures 20 to 60 feet and averages 30 feet thick. Normally its top is a few feet below the Brookville coal, and about 160 feet below the Middle Kittanning coal. The stratum, however, is characteristically irregular in lithologic character, thickness, and in its relation to the overlying beds of the Allegheny group. It is a cliff-making bed, frequently quarried along Beaver River from Beaver Falls to Wampum, and farther north in Edwards Run and Hickory Run. Along Connoquenessing Creek, however, and east of Beaver River between Chewton and New Castle the horizon of the Homewood is filled with shale. The altitude of

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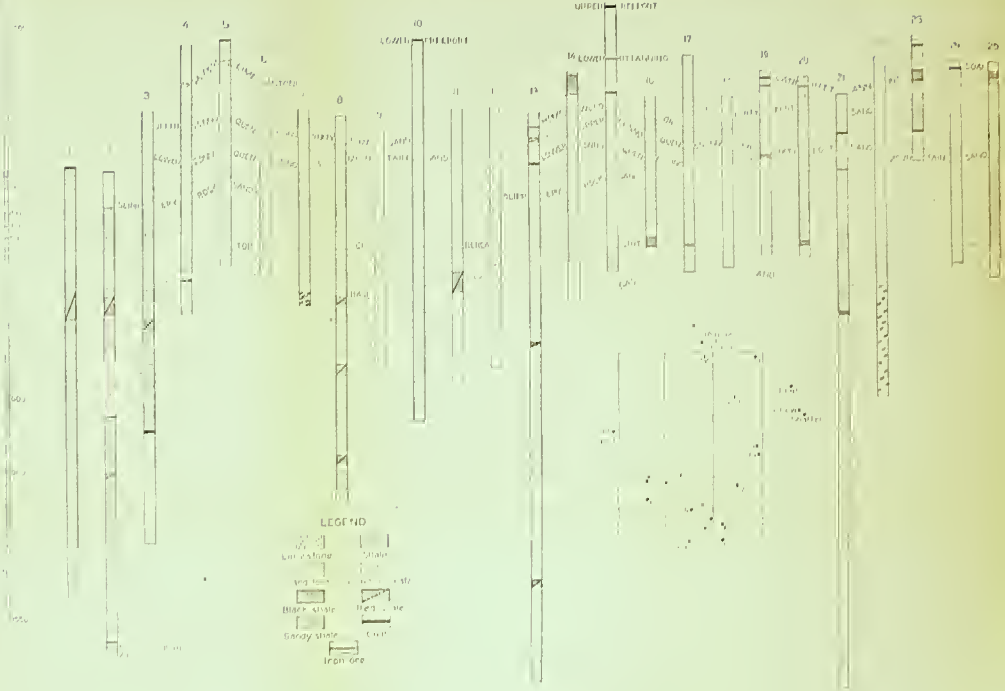
[13] Pennsylvania Second Geol. Survey, Vol. QQ, 1879.



1. Sharon, Second Survey Rept. QQ, p. 207
2. Shenango Iron Company, New Castle (215)
3. Robert W. White (251)
4. Geo. H. Moore, Slippery Rock Township
5. Warnock Heirs No. 1 (220)
6. W. M. Mehard (229)
7. Chew, Slippery Rock Township, Second Survey Rept. QQ, p. 89
8. Shaffer, Slippery Rock Township, Second Survey Rept. QQ, p. 161

Location of well sections*

9. E. W. Lichtenberger No. 1 (181)
10. Walker No. 1 (207)
11. Reese No. 1 (60)
12. McCandless Heirs No. 1 (1)
13. Pomeroy No. 2 (1), Second Survey Rept. QQ, p. 255
14. Welch No. 1, Chippewa Township
15. Sarah Craighead (61)
16. Haldeman No. 1 (165)

17. Hilyard Heirs (11)
18. Hugh Dunn (10)
19. John Mitchell (27)
20. W. N. McMillen No. 1 (102)
21. Fergus Johnson (125)
22. Carruthers No. 2 (133)
23. Bradford Heirs No. 1 (141)
24. R. A. Haney (165)
25. Andrew H. Fox (187)

*Numbers in parentheses are locations on Plate IV.

the bed changes in general agreement with the dips of the overlying coals already described, but the varying level of the top surface is partly due to uneven deposition. The determination of the thickness of the Homewood is difficult because most of the exposures fail to reach both top and bottom, and also because in stream sections it is frequently impossible to distinguish between true and false bedding planes. Thus the section at Homewood (No. 37, plate VIII), extending over one-quarter mile, shows apparent dip downstream, which makes the bed appear at least 25 feet thicker than it really is.

The name Homewood was given to this bed by I. C. White[14] because of its unusual development near the town of that name. The name is perhaps unfortunate since at the type locality the relations of the bed to the overlying Allegheny strata and to the underlying members of the Pottsville are not clearly understood. White regarded the underlying coal and shales as probably representative of the Tionesta or Mt. Savage and Mercer groups, underlain by the Upper Connoquenessing sandstone. The unusual thickness of 155 feet was regarded as due to the extension of the Homewood above its usual horizon to a position in the Allegheny beds above the horizon of the Vanport limestone. J. J. Stevenson[15] also regarded the Vanport horizon as being occupied by a sandstone which is continuous below with the Pottsville.

The accompanying sections offer a somewhat different solution of the problem and assume that the sandstone represents the Homewood and Upper Connoquenessing combined; and that there is room for the entire Allegheny series above its top, though somewhat thinner than usual. The conditions are thought to be similar to those described on Slippery Rock Creek.[16] The coal shown 30 feet above the massive sandstone is regarded as the Clarion. Along the road leading north from Homewood it underlies a shaly sandstone of light blue-gray color, which on lithologic evidence is the same as that already mentioned as occurring shortly below the Scrubgrass coal. It is regarded as possible that the Brookville horizon lies shortly above the Homewood sandstone. Across Beaver River, along Thompson Run, this light-blue rock has thicker bedding planes and is quarried. There it is underlain by thin coal streaks and a massive sandstone, regarded as Homewood. The reason for considering that the Connoquenessing and Homewood sandstones are united at Homewood is that the bed is unusually thick, and that the additional thickness seems largely to be at the base. Furthermore, the neighboring sections lend themselves readily to such an interpretation, and in the absence of fossil evidence, the facts seem to require it.

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[14] Pennsylvania Second Geol. Survey, Vol. Q, page 67, 1878.
[15] Bull. Geol. Soc. America, vol. 17, p. 104.
[16] Pennsylvania Second Geol. Survey, Vol. QQ, p. 84, 1879.

The most important observations on the Homewood sandstone are shown by the following table, supplemented by well logs and notes on oil wells.

Observations on the Homewood sandstone.

No. of location or section	Locality	Exposed thickness in feet	Altitude of top of exposure	Stratigraphic dist. of top below M. K. coal	Lithologic character	Quarried	Remarks
S31	Beaver Falls	20	720	195	massive, hard; medium grain	no	S. of quadrangle 1 m.
8	Eastvale	15	750	200	thick to thin-bedded, fine grain	no	
S32	South College Hill	30	830	150	thick to thin-bedded, fine grain	no	
11	Bennett Run	45	865	185	massive, thick and cross-bedded; conglomeratic to medium grain; coal streaks.	formerly	
281	Morado	20	880	155	massive to cross-bedded; hard	no	
306	Homewood	50	950	120	massive to thin-bedded; hard, conglomeratic.	yes	Continuous with Upper Conno. s. s.
S9	Thompson Run	40	930	140	massive to cross-bedded; coarse, hard.	yes	
S12	Bellton	20	870	155	massive; medium grain	formerly	
S39	Koppel	45	870	------	massive to shaly	yes	
S40	West of Koppel	15	895	145	massive to irregular-bedded	no	
	Hoytdale	30	880	160	massive to irregular-bedded	no	
332	Mouth of Possum Hollow	40	880	145	massive to thick-bedded; conglomeratic	formerly	
	Wurtemburg	35	900	165	somewhat massive	no	Vol. p. QQ, 74
86	South of Chewton	20	915	145	massive to cross-bedded; coarse	formerly	
88	East of Chewton	30	965	150	massive	no	
345	Wampum	50	885	145	massive; coarse to medium grain	formerly	
S46	Edwards Run	20	965	135	massive to irregular-bedded	no	
S48	N. W. of Moravia, 2 m.	30	1000	125	massive to thick-bedded;	no	
S28	Cascades, near Joyce	40	980	------	massive	no	
178	NE. of Joyce 1½ miles	20	1065	-----	massive and thick-bedded; medium grain; hard	no	R R cut
177	NE. of Joyce 2½ miles	20	1060	------	thick to thin-bedded; fine grain.	yes	
S51	SW. of Covert 1 mile	5	1010	------	massive	no	

Homewood (Tionesta) coal. The Homewood, Tionesta, or Mt. Savage coal occurs rather persistently below the Homewood sandstone or separated from it by not more than 5 feet of shale. In the absence of the sandstone in its normal development the coal is locally present at approximately the same horizon, which ranges from 135 to 220 feet, and averages 190 feet below the Middle Kittanning coal. It measures between 2 and 3 feet thick as a rule, but reaches a maximum thickness of 4 feet 2 inches; or it may be entirely absent or represented by thin streaks of bituminous matter imbedded either in sandstone or in a thin layer of shale or fire clay. At its best the coal is bony and sulphurous and is subject to frequent "rolls" caused by the encroachment of the roof sandstone into or below the horizon of the coal.

I. C. White correlated this seam with the Tionesta coal of the first Pennsylvania Geological Survey. Within this region the coal was formerly known by local names as "Dirt vein," "Four-foot," "Shields coal," etc.

Below the coal and above the Upper Mercer limestone occurs a stratum of shale which contains nodules and plates of iron carbonate and was formerly opened by drifts at numerous places north from Homewood. It is cut out in some places by unusual development of the Homewood sandstone, but otherwise averages about 10 feet in thickness.

The best observations on the Homewood coal are presented in the following table:

Observations on the Homewood coal.

No. of location or section	Locality	Thickness in inches	Altitude	Stratigraphic interval below M. K. coal	Bed overlying	Bed underlying	Remarks
24	NE. of Morado ½ mile	thin	880	180	sandstone	clay and sandstone	Quarry
25	NE. of Morado 1 mile	12	870	190	shale & sandstone	shale & sand stone	Quarry
S9	Thompson Run	------	890	200	sandstone	sandstone	
308	NE. of Homewood 1 mile	6–30	840	220	sandstone	shale	Beatty farm
S12	Bellton	thin	840	220	fire-clay shale	fire clay	
S40	W. of Koppel	thin	835	215	sandstone	shale & sandstone	
S16	Ellwood City tunnel	thin	925	150	sandstone	sandy fire clay	
453	Edwards Run	12–30	940	175	sandstone	sandy fire clay	
S48	NW. of Moravia 1½ mile	50	990	135	sandstone	fire clay	
456	SW. of mouth of Hickory Creek 1 mile	30	990	135	sandy shale	fire clay	
458	SE. of Mt. Jackson	28–32	1020	------	sandstone	fire clay	
459	Mt. Jackson	thin	1020	220	shale	sandy fire clay	
S51	SW. of Covert 1 mile	0–14	950	------	sandstone	shale	
S29	Mahoningtown	2	990	135	shale	sandy fire clay	
150	Union Valley	------	950	175	----------------	----------------	Old mine
	N. of Union Valley 1 mile	30–36	920	180	----------------	----------------	QQ, p. 148
178	NE. of Joyce 1½ mile	23	1045	------	sandstone	fire clay	RR cut

Mercer formation. The Mercer formation occupies the interval between the Homewood shales and the Upper Connoquenessing sandstone. It may be partly or entirely absent where either the overlying or underlying sandstone is developed beyond its normal limits. As exposed the group ranges in thickness between 15 and 75 feet, the average being about 30 feet. It includes, from the top downward, the Upper Mercer limestone, coal, and shale, and the Lower Mercer limestone, coal, and shale, in the order named. Although each of these beds is subject to local peculiarities, the Lower Mercer limestone is especially noteworthy for its persistence over a wide area. It occurs 95 - 150 feet below the top of the Vanport limestone, averaging about 135 feet; and 170 - 215 feet below the Middle Kittanning coal, the greatest being the distance where the other strata have a normal development. The Mercer exposures occur along the cliffs and tributary streams of Beaver River northward from Hoytdale; and along the Connoquenessing in the vicinity of Wurtemburg. Beyond the borders of the quadrangle the formation is present in much of the bituminous coal basin, especially in Mercer County, Pa., where it was studied and named by I. C. White.

The Upper Mercer limestone, which usually is 1 - 4 feet thick, is a hard, dense, fossiliferous, dark-blue rock. It contains nodules of iron carbonate and in places appears to be partly or altogether replaced by iron carbonate. It weathers along the joint planes and develops rectangular blocks of creamy or buff color. This is the Mahoning limestone of Rogers and the Upper Wurtemburg of Lesley and Lesquereux.

The Upper Mercer coal, where exposed, is 8 inches to 4 feet 8 inches thick, averaging about one foot. It is everywhere a shaly bed of little value. In some places it is reported to be split by accompanying limestone into two seams. Beneath the coal occurs a bed of non-plastic clay containing abundant remains of *Stigmaria.*

The Upper Mercer shale, where definitely limited between the accompanying limestone, is 10 - 25 feet thick. In the absence of the lower limestone it may continue downward another 10 feet to the Upper Connoquenessing sandstone. The shale is rich in nodules and plates of iron carbonate which are frequently concentrated in the basal portion; in the early days these were used as a source of iron along the Beaver and Shenango valleys.

The Lower Mercer limestone, 6 inches to 3 feet thick, is practically identical with the upper bed in lithologic character, and is regarded as somewhat more persistent in occurrence.

The Lower Mercer coal, where present, occurs immediately below the limestone or separated from it by as much as 15 feet of shale. It is 6 - 30 inches thick. It is more or less bony though in places a block coal of local value. It is the Lower Porter coal of Rogers, and is often referred to in this region as the "Blue limestone seam."

The Lower Mercer shale is 5-40 feet thick, depending on the development of the underlying sandstone. It is also a horizon of iron carbonate.

The most important observations on the beds of the Mercer members are summarized in the following table:

Observations on the Mercer Formation.

Number of location or section	Locality	Exposed thickness in feet	Thickness of Upper Mercer limestone in inches	Thickness of Upper Mercer coal in inches	Thickness of Upper Mercer shale in feet	Thickness of Lower Mercer limestone in inches	Thickness of Lower Mercer coal in inches	Thickness of Lower Mercer shale in feet	Altitude of Lower Mercer limestone	Stratigraphic interval from top of Vanport to top of L. M. limestone	Stratigraphic interval of L. M. limestone below M. K. coal	Remarks
S34	Morado	20	----	----	----	----	----	----	----	----	----	Bottom 270 below M K coal
	Hoytdale	20	----	8	20	----	----	----	----	----	----	Bottom 117 below M K coal Rept. V p 196
S41	Possum Hollow	16	----	----	---	12	+	15	850	----	190	QQ, p. 239
S16	Ellwood City tunnel	35	----	+	35	----	----	----	----	----	----	Coal 100 below top of Vanport
57	Wurtemburg	45	24	16	20	12	20	8	840	120	185	Part from QQ, p. 76
22	N. of Rock Point	10	----	----	----	+	----	5	880	120	190	
345	Wampum	20	----	----	----	22	16	10	810	150	215	
	Jenkins Run	23	----	----	----	28	18	10	900	----	----	QQ, p. 138
453 454	Edwards Run	50	18	----	20	24	6	35	895	120	205	
S47	Above Moravia	40	20	----	----	24	+	----	945	125	----	QQ, p. 139
S50	Mt. Jackson	25	48	24	20	36	----	15	975	95	170	Part from QQ, p. 128
161	N. of Union Valley	75	----	----	----	24	----	25	960	135	215	Part from QQ, p. 144
S29	1 mile NE. of Mahoningtown	45	24	9	20	24	----	5	950	110	----	
S52	Above Edinburg	40	36	56	----	20	30	----	980	110	----	QQ, p. 189 } Banks of Mahoning River N. of quadrangle
554	Quakertown	50	24	15	----	6	8	10	1045	115	----	QQ, p. 193
S53	Hillsville	40	36	18	25	20	20	----	990	150	----	QQ, p. 191

Upper Connoquenessing sandstone. The Upper Connoquenessing sandstone, or "Sixty-foot," is usually the second massive member of the Pottsville series, occurring next below the Mercer formation, and about 225 feet below the Middle Kittanning coal. It loses its massive character in some places, as at Mahoningtown; in others where the Mercer formation is absent, it appears to be continuous with the Homewood sandstone, as seen at the type locality of the later bed; and in other places it is probably continuous with the Lower Connoquenessing sandstone. Where exposed as a distinct sandstone it ranges from 5 to 84 feet in thickness, averaging about 40 feet. It is a massive bed, usually suitable for quarrying, but in many places shows variable bedding features. The texture is coarse but shows all phases from conglomerate to sandy shale. The color varies from white to yellowish brown.

The name Upper Connoquenessing was given to the bed by I. C. White because of its development as the upper wall rock along the creek of that name. The best observations on this sandstone are included in the following table. Its statigraphic relations are further indicated by well sections on plate X.

Observations on the Upper Connoquenessing sandstone.

No. of location or section	Locality	Thickness exposed	Altitude of top of exposure	Stratigraphic distance of top below M. K. coal	Lithologic character	Quarried	Remarks
281	Morado	60	840	210	Massive, coarse, white to buff	Formerly	Gwinner No. 1 quarry separated by 12 inch shale and coal from Homewood ss.
25	NE. of Morado 1 mile	30	870	190	Thick-bedded; medium to coarse grain; gray to yellow.	Yes	
S9	Thompson Run	50	890	180	Massive	No	Mostly boulders.
S37	Homewood	50±	900	170	Massive, medium grain, gray	No	Continuous with Homewood.
38	NE. of Homewood 1 mile	20	835	215±	Massive	No	
S12	Near Bellton	50	800	270		No	Rept. V. p. 192. Top of sandstone not definite.
49	S. of Rock Point	84	840	260	Thin-bedded; fine grain		Rept. V, p. 190. Probably joined to lower Connoquenessing.
49	Rock Point	25	850	200	Massive to thin, cross bedded; white to brown.	Yes	Skillen quarry.
S40	West Ellwood Jct.	40	830	180	Massive	No	
	Hoytdale	60	880	155	Massive		In part from Rept. V. p. 196.
S41	Possum Hollow	20	830	200	Massive; white	No	Rept. QQ, p. 239.
	Slippery Rock Creek, 1½ mile below mouth of	50	900	200	Massive; coarse grain	No	Rept. QQ. p. 97.
S16	Ellwood City tunnel	40	870	205	Massive to cross-bedded; coarse to medium grain; yellow	No	
	Wurtemburg	35	860	200	Coarse grain, gray	No	Rept. QQ, p. 74.
S22	Between Rock Point and Chewton	90	870	190	Massive; coarse grain; gray	No	
343	Wampum	40	830	240	Massive to irregular-bedded; coarse	Yes	Beaver Valley SS. Co.
145	N. of Irish Ripple ½ mile	40	850	230	Thick-bedded and shaly	Yes	
362	Jenkins Run	73	850	230±	Massive; coarse grain	No	Rept. QQ, p. 138
S46	Edwards Run	40	830	250	Massive to irregular bedded; light gray to yellow	No	
S49	Hickory Run	60	960	175	Massive; hard, gray conglomerate to coarse grain.		Thickness doubtful.
S29	Mahoningtown	5	935	200	White; hard	No	Gives way to shale.
192	New Castle	8	850	200	Massive; gray to yellow	No	Hill w. of high pressure reservoir.
S54	Quakertown	45	1025	250	Massive; hard; white	No	Rept. QQ, p. 193. Outside of quadrangle.

Quakertown coal and shale. The Quakertown coal lies beneath the horizon of the Upper Connoquenessing sandstone, and about 265 feet below the Middle Kittanning coal. It seems to be absent in many places and is practically never of minable thickness, ranging up to 22 inches. Below the coal occurs fire clay and shale which is characteristically ferruginous like the Mercer shales. It is 60 feet thick at Homewood but more commonly measures 30 feet or less.

This bed was named by I. C. White from the occurrence near Quakertown, Pa., about 4 miles north of Bessemer. It persists as a thin coal or bituminous shale in much of Lawrence County and is known along Mahoning River, Beaver River, and Connoquenessing Creek.

The most important observations on this coal and shale are noted in the following table:

Observations on the Quakertown coal and shale.

No. of location or section	Locality	Thickness of coal in inches	Thickness of shale in feet	Altitude of top of exposure	Interval from M. K. coal to Quakertown coal	Remarks
S34	Morado	0—6	20	780	270	Iron carbonate present.
25	NE. of Morado 1 mile	Thin		840	220	Base of quarry.
S9	Thompson Run	2	5	830	250	
S37	Homewood	Thin	60	820	250	Another coal streak in shale and an 8 in. bed also.
S40	West of Koppel Jct.	Thin	5	750	300	
	Rock Point		10	760	290	Sandy shale.
	Wurtemburg	16	5	780	280	Vol. QQ, p. 74. Slaty coal.
S22	Between Rock Point and Chewton.		20	800	260	Vol. QQ. p. 99.
343	Wampum	Thin	30	790	240	Streaks of coal at base of quarry.
146	N. of Irish Ripple 1 mile	22		810	275	7 inches shale in middle of coal.
S46	Moravia		5	785	300	Iron carbonate.
165	S. of New Castle Jct. ¾ mile.	Thin	25	930	200	Iron carbonate above coal horizon. Old shale pit.
S49	Hickory Creek		20	885	240	Iron carbonate.
S29	Mahoningtown		20	930	210	
184	NE. of New Castle Jct. ¼ mile.	8	30	920	210	Coal below iron-bearing shales.
182	New Castle	Thin		970	200	Coal streaks at base of quarry N. of Rigby.
S27	New Castle		7	845	330	Iron carbonate near level of Big Run east of Rigby.
S51	Covert	18	10	900	250	Vol. QO, p. 140.
S52	Edinburg	12		940	210	Vol. QQ, p. 189. N. of quadrangle. Possibly local coal.
S54	Quakertown	0—12	3	980	200	N. of quadrangle.

Lower Connoquenessing sandstone. The Lower Connoquenessing sandstone is the lowest massive bed exposed in this region. It is separated from the Upper Connoquenessing by the Quakertown coal and shale horizon and where seen lies about 285 feet below the Middle Kittanning coal. It is a coarse-grained, white rock, usually massive or thick-bedded; in places, however, it may be conglomeratic or shaly. Along Connoquenessing Creek where its name was given to the bed by I. C. White the sandstone is brown and ferruginous. The exposures of this bed range from 5 to 75 feet in thickness, averaging 40 feet where the development is not abnormal.

This is probably the so-called "Big Injun" sand of the Purdy pool, and of some other wells.

Sharon shale and coal. The Sharon shale is exposed below the Lower Connoquenessing sandstone along Connoquenessing Creek and along Mahoning River from Hickory Run to the Ohio line. Except at Quakertown the exposed shale is less than 10 feet thick and is a bluish-gray mass, containing iron carbonate nodules. Near the base of the shale may be seen occasional stringers of coal or bituminous shale which represent the Sharon coal. At Quakertown (section 54, plate VIII) the coaly shale, which is 2½ feet thick, lies at an altitude of about 845 feet. Farther west and north the coal is well developed in more or less local areas where it is a highly prized block coal.

Observations on the Lower Connoquenessing sandstone.

No. of location or section	Locality	Thickness of exposure in feet	Altitude of top of exposure	Stratigraphic interval below M. K. coal	Lithologic character	Remarks
S37	Homewood	5	740	335	Thin-bedded; white; hard.	
	Connoquenessing Creek, 1 mile below Wurtemburg.	20	820	280	Massive; coarse grain; brown.	QQ, p. 97.
S45	Wampum	4	760	265	Yellow.	
S49	Hickory Run	50	870	260	Massive to thin-bedded; fine grain; gray to buff.	
166	S. of New Castle Jct. ½ mile.	25	850	280	Thick-bedded; fine grain; white.	
S29	Mahoningtown	25	860	280	Massive to thin-bedded; fine grain; white.	Above Lawrence School.
187	Mahoningtown	20	820	320	Massive; white and yellow.	Old quarry opposite box factory.
	New Castle	50	------	------	Massive; coarse grain; grayish white.	QQ, p. 67. Along "Narrows of the Shenango".
S51	Covert	75	890	260	Conglomeratic at top; shaly below.	QQ, p. 140.
S52	Edinburg	27	920	230	Massive; fine grain; white.	QQ, p. 189. Beyond quadrangle.
S56	Quakertown	100	9[illegible]0	205	Massive and thin-bedded; including shale bed.	QQ, p. 183. Beyond quadrangle.
S53	Hillsville	25	970	275	Massive; coarse grain.	QQ, p. 191. Beyond quadrangle.

ROCKS NOT EXPOSED.

Sources of information. The unexposed rocks of this area are known only from the records of deep wells drilled in search for oil or gas. Such records are imperfect because of several sources of error.

The kind of rock is judged only from casual examination of the drillings brought up by the sand pump or from the relative ease with which the beds are penetrated by the drill or from their wearing effect on the cutting edges of the bits. Thus the driller fails to record the presence of certain thin coals, red rocks, and limestones which may be of great interest to the geologist; and is able to detect only the wider variations in material, texture, and color of the beds. The thicknesses of the various strata and their distances from the surface are, as a rule, but approximately determined by estimating the length of cable used. The errors introduced by this method supplemented by the stretching of the rope itself may be considerable, and only a few measurements to important sands are made with steel line. Nevertheless, the logs reveal certain facts which, by interpretation, show the position, distribution, and general character of the various strata and their relations one to another.

Thickness. The rocks below the horizon of the Sharon coal, which marks the base of the exposed beds, have been penetrated to a depth of 2700 feet. This is the depth of the Shenango Iron Company well at New Castle, No. 245 on plates V and X, which begins at the Sharon horizon. Two other wells, that of the Economy Society at Beaver Falls (No. 1), and that of Fergus Johnson (No. 125), near Darlington, reach a depth 2500 feet below the Sharon. Altogether eight wells of the quadrangle or vicinity have been drilled 2000 feet or more, and the best records obtainable are here published.

General character. The unexposed strata vary greatly in character but show considerable uniformity in the Berea and immediately underlying beds. This fact makes it desirable to consider the rocks in three classes: (1) the variable beds above the Berea, measuring about 325 feet thick; (2) the Berea and Gas sands, which are 150 —200 feet thick; and (3) the variable beds below the Gas sand, including about 2200 feet of strata.

Variable beds above the Berea. Extending from the Sharon coal horizon to the Berea sandstone there seems to be a body of shales or sandy shales but in some areas there are heavy sandstones of prominence, especially near the top of this division. Drillers recognize the Slippery Rock oil and Salt sands, each about 35 feet thick and separated by 5 to 10 feet of shale. In the early days the top bed, which lies about 450 feet below the Middle Kittanning coal, produced oil just east of the quadrangle margin in the Slippery Rock pool. Even here the bed is locally absent or overlooked, as indicated by the log of the Shaffer well* (Pl. X). In many wells a sandstone in this position is regarded by drillers as the Big Injun. The correlation is doubtful, as explained later. Just above the Berea a black shale which may be as much as 25 feet thick is found in many wells.

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*Pennsylvania Second Geol. Survey, vol. QQ, p. 154

*Berea and Gas sand.** These beds occur at the base of the variable gray shales and sandstones and are present under most of the area. The top member, or Berea, (the most important oil rock of the region) is usually reported to be 30 to 40 feet thick, with its top about 710 feet below the Middle Kittanning coal or about 630 feet below the Vanport limestone. It is a light-gray to white, quartzose rock, usually of fine texture but locally reported pebbly. Very exceptionally the bed is reported absent or combined with the next underlying Gas sand, from which it is usually separated by a shale bed 5 to 40 feet thick. This lower sand, which is the chief gas-producing stratum, is 40—90 feet below the top of the Berea and is 75 - 100 feet thick, though locally as thin as 35 feet.

Rocks below the Gas sand. Since few logs of wells deeper than the Gas sand are available, the lower rocks are not well known. They have been penetrated to a depth of 2200 feet or more and consist of shale with a few thin beds of sandstone. The highest red shale of the unexposed rocks occurs near the top of this division, usually from 25 to 100 feet below the base of the Gas sand; and this red color is prominent in the lower beds. The distribution of the lower sandstones cannot be stated. A number of records indicate a bed, which has been called the Hundred-foot, just below the first red rock and 50—125 feet below the base of the Gas sand. Another bed 250 feet below the Gas sand has yielded gas near Ellwood City and has been called the Third sand. In a number of logs of wells in the northern part of the area a sandstone shown in this position may be identical with that at Ellwood City.

Correlation of unexposed rocks. During the work of the Second Pennsylvania Geological Survey I. C. White, John F. Carll, and H. M. Chance studied the correlation of the beds penetrated by deep wells in this region. More recently studies have been made for the U. S. Geological Survey in the Kittanning quadrangle, 25 miles to the east, by Charles Butts and in the Beaver quadrangle, which joins the New Castle area on the south, by L. H. Woolsey. The Pottsville series of the Appalachian region has been correlated by David White on paleobotanical evidence, and general correlation studies of the Carboniferous have been made by J. J. Stevenson on stratigraphic evidence. All of these progressive studies, by testing various hypotheses, have been important features in solving the geology of this quadrangle. In the light of numerous well records collected in the present survey, a summary of evidence on correlation is desirable.

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*Since this survey was made Mr. C. S. Prosser of the Ohio Geological Survey has presented evidence to show that the Berea sandstone when traced into Crawford County, Pa., divides into two sandstones which the Second Geological Survey called the Corry and Cussewago sandstones, separated by the Cussewago limestone and shale. It is suggested that further study may show that the two sandstones encountered in drilling in this area correspond with the Corry and Cussewago. Whether these and the intermediate rock are all equivalent to the Berea or only the top bed must await further studies.

The well sections illustrated on plate X indicate the presence below the Allegheny group of three series or groups of rocks, which in descending order are Pottsville, Pocono, and Catskill . The Pottsville has its upper boundary exposed in the quadrangle and definitely marked in many places, but its lower limit is doubtful. The basal member to the north in Mercer County is the Sharon conglomerate, according to I. C. White,[17] Carll,[18] and David White,[19] though Chance[20] has argued in favor of including two lower sandstones.

Following the prevailing opinion the base of the Sharon conglomerate is regarded as the bottom of the Pottsville in the New Castle area, but it is variable in character and is probably represented only by outlying patches. Furthermore, the proximity of underlying sandstones makes separation difficult. Thus I. C. White regarded the Sharon as absent at the mouth of Hickory Run in North Beaver Township,[21] and absent in the Chew well in Slippery Rock Township,[22] but present at Wampum,[23] and at Beaver Falls [24] as shown by well No. 1. Later he was inclined to regard the "supposed" Sharon at Beaver Falls as Shenango.[25] Chance on the other hand represents the Sharon as present throughout the length of his profile from Sharon to Homewood.[26] The Slippery Rock oil sand in the Chew well was regarded as Sharon by Carll,[27] though White considered this bed well below the Pottsville. Thus it is clear that the dividing line between the Pottsville and older rocks is difficult to determine on stratigraphic grounds.

The Mauch Chunk series was thought by Carll to be represented by the Shenango shales which next underlie the Sharon conglomerate.[28] The age of this bed, only 30 to 50 feet thick, has never been finally determined. The studies of Butts[29] and Woolsey[30] show that the real Mauch Chunk is probably absent in adjoining areas because of erosional unconformity. Inasmuch as the shale does not possess the red color characteristic of the typical Mauch Chunk, it would probably be placed with the Pocono on stratigraphic evidence. Carll assumes, however, that it has been traced to Warren where collections of fossils establish its age.[31]

The Pocono series here has indefinite boundaries at top and bottom. The Shenango and Sub-Olean sandstone, next below the Sharon, is regarded as Pocono by Carll[32] and White.[33] This sandstone, as shown by the sections, lies at or near the place of the Slippery Rock oil sand which presumably belongs in the Pocono. Sandstones at this general horizon have been identified by some drillers as Big Injun or by others as Mountain, but the same names elsewhere have been applied to beds undoubtedly higher in the column. It does not seem likely that the Slippery Rock sands represent the entire Big Injun as described by Butts.[34] It has been shown by him and by Woolsey that erosion has removed not only the Mauch Chunk but locally, much of the top of the Pocono, and it is probable that this unconformity occurs between the Slippery Rock oil sands and the bottom of the Pottsville. Evidence, however, makes it possible to suppose that the Slippery Rock sands were laid down as the first Pottsville sediments after the period of erosion. According to this view the Pocono beds above the Berea Grit in this area would consist essentially of shale. Carll correlated the Ohio Berea which is underlain by the Bedford red shale with the Pennsylvania Pithole Grit[35] or Butler "First Sand" underlain by its red shale.[36] His view seems reasonable and so far as evidence is available is supported by the present studies. The Berea here has an overlying black shale similar to that noted in Ohio.[37] There is no rock under the Berea in Ohio which corresponds to the Gas sand of the New Castle area. Probably both sands are contemporaneous with Berea, or more accurately, with the Corry and Cussewago sandstones as described by White.[38] The base of the Pocono was placed at the top of the "First Sand" of the Venango-Butler oil group by Carll and thus included his Crawford shales, which contain the Berea Grit.[39] The Bedford shale under the Berea, however, is provisionally made the top of the Catskill by Woolsey, since the base of the Berea group offers a distinct line for this arbitrary boundary. Butts placed the bottom of the Pocono at the base of his Second or Hundred-foot sand. Beneath it occur Catskill beds which are characterized by the presence of red shales. Comparison of sections from the regions referred to invite the view that the red rocks occur at practically the same horizon in these localities, and that in the New Castle and Beaver quadrangles Butts' Hundred-foot is stratigraphically the same as the Berea and Gas sand combined. If this is not true then the Bedford red shales do not appear in Butts' sections.

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[17] Pennsylvania Second Geol. Survey, Rept. QQQ, p. 33.
[18] Pennsylvania Second Geol. Survey, Rept. I 5, p. 126.
[19] Geological Society of America, Vol. 15, p. 268.
[20] Pennsylvania Second Geol. Survey, Rept. V, p. 225.
[21] Pennsylvania Second Geol. Survey, Rept. QQ, p. 124.
[22] Idem, p. 89.
[23] Idem, p. 113.
[24] Idem, p. 257.
[25] Pennsylvania Second Geol. Survey, Rept. Q4, p. 72.
[26] Pennsylvania Second Geol. Survey, Rept. V. (profile).
[27] Pennsylvania Second Geol. Survey, Rept. I 5, p. 112.
[28] Pennsylvania Second Geol. Survey, Rept. I 5, p. 105 and III, p. 20.
[29] U. S. Geol. Survey Geol. Atlas, Kittanning folio No. 115.
[30] U. S. Geol. Survey Geol. Atlas, Beaver folio No. 134.
[31] Pennsylvania Second Geol. Survey, Rept. III, p. 21.
[32] Pennsylvania Second Geol. Survey, Rept. I 5, p. 105.
[33] Pennsylvania Second Geol. Survey, Rept. Q 4, p. 77.

The Catskill rocks of this area are arbitrarily regarded as extending from the top of the Bedford red shale downward an unknown distance. Doubtless the Venango lower sands are represented by some of the sands and "shells" below the red shale of the accompanying sections, but as Carll has shown that the sands die out to the west of the Venango-Butler region, close correlation is not possible.

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[34] U. S. Geol. Survey, Geol. Atlas, Kittanning folio No. 115.
[35] Pennsylvania Second Geol. Survey, Rept. III pp. 93-97.
[36] Pennsylvania Second Geol. Survey, Rept. I 5, p. 103.
[37] Ohio Geol. Survey, Vol. 1, p. 209, Vol. 2, p. 90 and 212.
[38] Pennsylvania Second Geol. Survey, Rept. Q 4, p. 67.
[39] Pennsylvania Second Geol. Survey, Rept. I 5, p. 93.

STRUCTURE.

General statement. Knowledge of the attitude or lie of the strata is of considerable value, both in mining operations and in prospecting for oil and gas. Although the various beds were originally laid down under water as unconsolidated sediments in approximately horizontal position, they no longer have that attitude, but are undulating or gently folded. Such folds, when mildly ridge-like in form, are termed anticlines, and where they are trough-like they are termed synclines. In an anticline, the strata slope or dip away from the highest line or axis of the fold, and in a syncline they dip toward the axis of the trough.

In making field observations the structural conditions are determined by noting the change in altitude of the various beds from place to place. This feature is, perhaps, best illustrated by reference to data shown on the Economic Geology map, Plate IV. If a line be drawn from the hilltop one mile west of Enon Valley to the southeast corner of the map, it passes near a number of country banks and outcrops of the Upper Freeport coal, which rises in altitude from the extremities toward the middle in response to an anticline whose axis lies about one mile west of Morado. The geologic relations along this line A-B are further clarified in the corresponding cross-section.

The axis of a syncline is shown just west of New Galilee. The varying altitudes are shown in the following table:

Altitude of Upper Freeport coal.

No. of location or section	Location	Feet
321	New Galilee	1,095
318	SE. of New Galilee 1 mile	1,130
301	SE. of New Galilee 2½ miles	1,145
288	NW. of Morado 1½ miles	1,195
S35	NW. of Morado ½ mile	1,180
22	SE. of Morado 1 mile	1,150
12	SE. of Morado 2 miles	1,105
2	NW. of SE. corner 1½ miles	990

Method of representing structure. Instead of preparing a great number of cross-sections to indicate the structure of the rocks, contour lines are used which show the altitudes of the top of the Middle Kittanning coal bed. This datum plane was selected because, considering the area as a whole, this is the most widely distributed bed which is readily identified. The altitude of this coal bed above sea

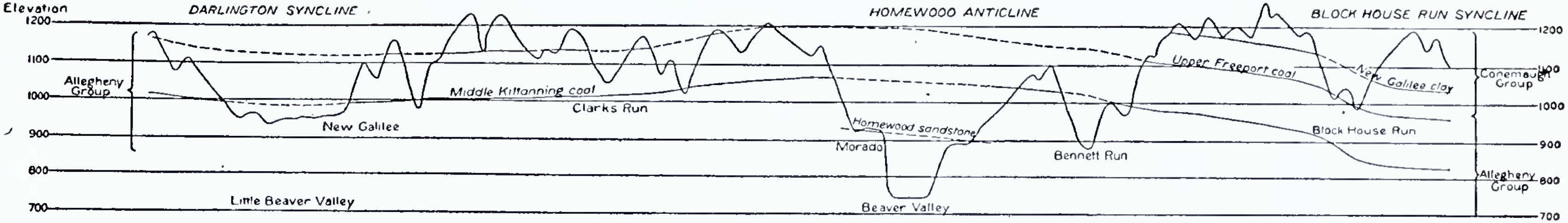

FIGURE 2. Cross section of New Castle Quadrangle showing major structure. Vertical scale exaggerated.

level was determined wherever possible either at openings or blossoms of the coal itself or by calculating its position from observation of certain exposed beds which are recognizable and whose stratigraphic distances from the Middle Kittanning coal were known. Thus, in as much as east of Beaver Falls, in section No. 3 (Pl. VII), the Upper Freeport coal is exposed 120 feet above the Middle Kittanning coal, therefore the altitude of the Middle Kittanning was calculated at other places in the vicinity where the Upper Freeport was exposed by subtracting 120 feet from the observed altitude of the upper bed. Similarly, 1 mile north of Union Valley in section No. 24 (Pl. VII) the Middle Kittanning coal occurs 80 feet above the top of the Vanport limestone, and that amount was added to the observed altitude of the limestone at other outcrops in the same vicinity in order to approximate the probable altidude of the coal. In some places the coal still remains in the hill tops. In others, erosion has removed it and the calculated altitude represents its position before erosion.

When the various observations and calculated altitudes of the Middle Kittanning coal were placed on the map they ranged from 825 feet above sea level in the southeast corner of the map, to 1240 feet near the northeast corner. The 1000-foot contour line on the map connects all the points where the Middle Kittanning coal is 1000 feet above sea level. Other contours express differences of 25 feet in elevation. The contour as thus drawn indicates the altitude of the Middle Kittanning coal at all places in the quadrangle, the direction of dip (at right angles to the contours), and the approximate amount of dip, in feet, between any two points separated by one or more contours. They also indicate the form and magnitude of structural folds and irregularities.

The representation of structure is subject to three chief sources of error. In most cases the elevations of the numerous datum points were determined by barometer readings checked on road intersections or other points whose elevation is probably correctly represented on the topographic map. A minor number of determinations was made by means of the Locke hand level. Wherever the topographic map itself is in error, this method of determining elevations of datum points may make the mapping of the structure incorrect. In the second place, because the strata are not perfectly parallel and the interval from the Middle Kittanning coal to various beds above and below its horizon is not identical in all parts of the area, as already noted in the discussion of stratigraphy, it is possible that the interval assumed at certain places is slightly in error. In the third place, a source of error exists in the assumption that between two datum points showing a difference in elevation of the key rock, the dip is uniform, whereas in reality the bed may lie nearly or quite flat for a portion of the distance and be steeply inclined for the remainder. The probability of such error increases with the increase of distance between datum points. These several errors may compensate or may combine to render the total error considerable, but in general it seems probable that the amount of error will average within the contour interval, or 25 feet for that portion of the quadrangle west of Beaver River and south of Wampum, and east of Beaver River and south from Union Valley. In the remainder of the area, outcrops on which to base calculations are scarcer because of the thickness of glacial deposits and the error may be somewhat greater and possibly erratic. Although possible errors mentioned may make the indicated elevation of the Middle Kittanning coal incorrect at various places, yet such errors but slightly affect the relative dips in any local area, because determinations at neighboring datum points are all largely affected by the same error; thus the relative conditions are the same as depicted on the map. Lack of parallelism in the strata may lead to some error when this map is used to determine the structure of the oil sands many hundreds of feet below the Middle Kittanning coal. Thus an anticline in the Middle Kittanning coal may not exactly overlie an anticline in the oil sands several hundred feet lower.

The structure sheet offers valuable data to the miner and to the oil operator, for new mines should take advantage of the dip of the beds so as to obtain, if possible, natural drainage and down grade haulage for loaded cars. As will be shown later, the accumulation of oil and gas in large quantity is probably controlled in part by the dips of the sand. Further explanation of the relation of structure to oil and gas is given under the later chapter devoted to petroleum.

Use of structure contours. At any given point on the map the vertical distance to an overlying or underlying bed can be approximated in the following manner: Determine the altitude of the Middle Kittanning coal for that point by referring to the structure contours (interpolating between contours, when necessary), and add to or subtract from that figure an amount equal to the stratigraphic interval from the Middle Kittanning coal to the bed sought, adding if it overlies and subtracting if it underlies that coal. This gives the altitude above sea level of the desired bed. If this figure be compared with that representing the altitude of the surface of the ground at the point of observation, as shown by conteurs on the topographic map or as determined by a level line from some point of known altitude, the difference between them represents the vertical distance to the bed sought. Stratigraphic distances of beds from the Middle Kittanning coal are given under the chapter on Stratigraphy and in more detail in the later notes which describe the geology of local districts. For the distance to the various oil and gas sands, see the chapter on petroleum.

Description of structure. The structure is not simple enough to be adequately described in a general statement, but requires detailed description for local regions. The most striking feature, perhaps, is the absence of persistent well-marked anticlines and synclines, and the presence of minor structural spurs, hollows, and various irregularities of local extent. The dips are neither uniform in direction nor amount. In the southern part of the quadrangle there is a broad anticlinal fold with an axis passing northeast and southwest through Homewood, which is relieved by a fairly definite syncline on the western bank and on the eastern slope by local basins in Blockhouse Run and at North Sewickley. A cross section of this anticline is shown in figure 2. It may be named for convenience the Homewood anticline, and the basin on the west the Darlington syncline.

In the northern part of the quadrangle there are two structural elevations, separated by a gentle syncline which agrees in general position with the Beaver Valley. In the vicinity of Chewton, the dip is 100 feet per mile to the southwest, but west of Beaver River it averages rather less than 25 feet per mile.

In this area the data are inadequate for detailed determination of the structure but the general relations are probably as indicated on the map. The West Ellwood anticline and Covert basin appear to be definite features, but calculations are rendered doubtful because of reliance on the Homewood coal, which lies at a varying distance from the Middle Kittanning coal.

Disregarding local irregularities, however, the general dip is southward and considering the quadrangle as a whole, it averages about 25 feet per mile. This is exceeded in several places. One already mentioned is the locality near Chewton, where the dip is 100 feet per mile to the southwest. Another is in the Blockhouse Run basin where the dip is 100 feet per mile to the southeast. An eastward dip of the same magnitude is shown from the hill east of Bellton to Connoquenessing Creek. In the southwest corner of the quadrangle, along Brush Run, the dip is westward about 75 feet per mile.

Joined with the effects of erosion, structure has given a varying extent of outcrop to different strata. In general, the northern edge of the quadrangle lacks the beds above the Middle Kittanning coal, the hilltops being occupied by limestone at an elevation 350 feet above the river. Passing southward, the limestone occurs deep in the valleys, and at the south margin of the area it lies but 40 feet above river level. There the Conemaugh beds, 400 feet stratigraphically above the Vanport limestone, are in the hilltops. The structure will be described in more detail beginning in the southeast corner of the quadrangle.

Blockhouse Run syncline. The Blockhouse Run syncline, because of its double-pitch axis, forms an elliptical basin. Trending northeast and southwest its longest diameter is about 3 miles, and its center lies half a mile south of the New Castle quadrangle; hence only the north side is represented on the accompanying map. The beds of this basin dip from all sides toward the center, at a rate of 50 to 75 feet per mile. The structure of this area was determined mainly from observatoins on the Upper Freeport coal.

North Sewickley syncline. Near North Sewickley there appears to be a northwest-southeast trough, whose axis descends toward the east. Its flanks rise to the Homewood anticline and to a small fold which extends eastward to the road forks between North Sewickley and Wurtemburg. The structure of this district was worked out from calculations on the Kittanning and Clarion coals and the Vanport limestone, but data are in part lacking because of the masking of outcrops by the alluvial deposits of the valley and because of the thinning of the limestone.

Homewood anticline. The Homewood anticline, as shown on Plate V, rises as a broad sloping surface from a structural depression which follows the direction of Ohio River, from Beaver to Smiths Ferry. Its axis does not follow a straight line, but from Smiths Ferry it passes 1 mile east of Fairview and Blackhawk and enters the New Castle quadrangle where the margin is cut by the line between South Beaver and Chippewa townships. From there it passes in a nearly straight line northeastward to Homewood, where it veers first to the east, crossing Beaver River, then to the north and northeast, along the ridge which separates the basins of Connoquenessing Creek and Beaver River. At Ellwood City it crosses the Connoquenessing and from there rises rapidly northward toward Energy. Throughout its course the crest of the anticline rises toward the northeast as shown by the map, and is considerably higher in the Zelienople quadrangle (adjoining the New Castle quadrangle on the east) where it passes through Rose Point and Grant City as a well-defined structure. The eastern slope of the fold is more regular and longer than the western slope. The latter shows small northwestward spurs in South Beaver Township, and irregular fluting at Wampum and Homewood. The effect of this fold as shown in plate IV is to raise the Upper Freeport coal from the deepest part of Blockhouse basin to the crest of the anticline west of Morado, from which place it gradually descends northwestward to the Darlington syncline. Along the crest of the anticline the rise of the axis carries the Middle Kittanning coal from an altitude of 1025 feet at the south edge of the quadrangle, to 1100 feet near Ellwood City, where it further rises more rapidly to Energy. This coal has an elevation of 1300 feet at Grant City only a few miles farther northeast.

Darlington syncline. The lowest part of the Darlington syncline within the quadrangle is enclosed by the 900-foot structure contour in South Beaver Township. From there the rising axis passes northeastward to Darlington, and swings nearly north to New Galilee, where it turns northeastward again to Wampum, and runs out as a minor fluting northeast to Chewton or swinging northward again passes up the Beaver Valley to New Castle. This is a board basin, poorly defined, and probably contains minor warpings other than those indicated on the map. The effect of the fold is illustrated by the variations in the elevation of the Middle Kittanning coal which rises along its axis from an altitude of 900 feet in the deepest part noted, to 975 at Darlington, 1000 at New Galilee, and 1025 at Wampum. The flanks of the syncline rise gently southeastward to the Homewood anticline, and northwestward to the broad elevated area of that region.

West New Castle anticline. The axis of the West New Castle anticline passes southwestward from that town, descending to Edwards Run, and possibly continuing onward to Beaver Dam Run. From its highest portion along the north edge of the quadrangle, the beds dip eastward into the Darlington syncline, westward to the Covert syncline, and southward. The fold loses its strength southward and merges into the general monocline indicated. The shape of this anticline is calculated largely on the basis of changes in elevation of the Homewood coal and Upper Connoquenessing sandstone, but as these beds are not always parallel to the Middle Kittanning coal, the structure based on these data must be regarded as generalized.

Covert syncline. The Covert syncline is a basin-like structural depression, centering about one mile southwest of Covert. The most important datum is the coal outcrop near the middle of the basin, which according to a section along the ravine studied by I. C. White before the construction of the railroad, is to be regarded as the Homewood coal. On this basis the Middle Kittanning coal, before erosion, was bowed downward from the margin of the basin, where its altitude was about 1150 feet, to an altitude of 1100 or less. However, owing to paucity of information it has been necessary to generalize the structural representation.

DETAILED ECONOMIC GEOLOGY

INTRODUCTION.

This section presents the economic features of the geology of the coals, fire clays, and building stones of the New Castle quadrangle. A few subjects, such as oil and gas, water supplies, and limestone and lime receive further consideration in subsequent sections.

The discussion is arranged, for convenience, by districts and sub-districts, the latter being further sub-divided where advantageous. The districts and sub-districts chosen for this purpose are as follows:

- Southeastern District
    - Beaver River sub-district
    - Connoquenessing Creek sub-district

- South Central District
    - South Beaver sub-district
    - Beaver Falls sub-district
    - Big Beaver (Beaver Co.) sub-district
    - Lawrence County sub-district

- Western District
    - Southern sub-district
    - Northern sub-district

- Northwestern District
    - Southern sub-district
    - Northern sub-district

- Northeastern District
    - Southern sub-district
    - Northern sub-district

So far as possible, natural prominent objects (mainly streams) have been selected as boundaries of the divisions. The arrangement of the districts and sub-districts within the quadrangle boundaries, and their relationship to each other, is shown in Figure 3.

Ravine and well sections (see Plates VII, VIII and IX) are arranged in 3 groups, from south to north, disregarding districts. One of these groups consists of the sections east of Beaver and Mahoning Rivers; another group, the sections just west of those streams; and the third group, a series found northward from the southwest corner of the area.

Individual outcrops, mines, or borings bear numbers in the text which correspond to numbers on the map (Pl. IV). These are arranged in approximate sequence from south to north for each district as a unit. This device permits ready reference on the map to those localities mentioned in the text; and numbered localities on the map conversely, may be easily found in the text.

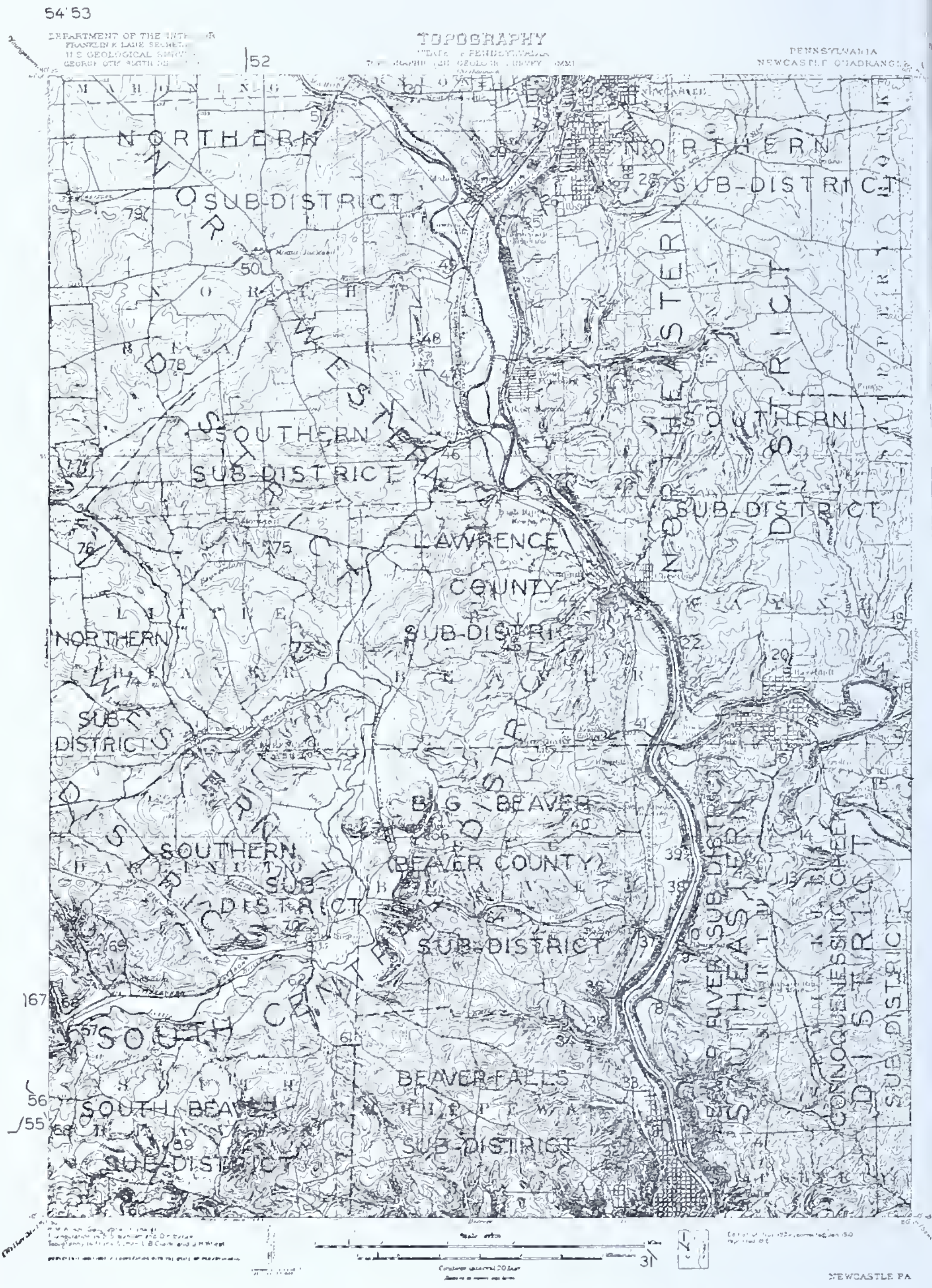

FIGURE 3. Key map showing districts and subdistricts and localities where stratigraphic sections were measured.

SOUTHEASTERN DISTRICT.

GENERAL STATEMENT.

The southeastern district is separated from adjoining districts by Beaver River, Connoquenessing, and Slippery Rock creeks, as shown by the sketch map (fig. 3). Except for terraces and flood plains along the streams, the district is a rugged, dissected upland of considerable relief, and with drainage deflected about equally into the Beaver and Connoquenessing from an irregular divide which extends diagonally from the southeast to the northwest corner. Railroad service is afforded by the Pennsylvania, the Pittsburgh & Lake Erie, and the Baltimore & Ohio lines and these offer exit from any spurs which may be constructed along the side ravines, like that now serving Thompson Run mines. It is one of the richest districts in coal, fire clay, sandstone, and shale, besides possessing small areas of thick limestone in the northern end and terrace clay of value. The former production of natural gas in the vicinity of Eastvale and of Ellwood City offers possibilities of further development.

GENERAL GEOLOGY.

Stratigraphy.

Introduction. The exposed Carboniferous rocks measure approximately 730 feet in thickness and are divided into the Conemaugh, Allegheny, and Pottsville groups already described under Stratigraphy. There are additional unconsolidated fluvial deposits along the Beaver and Connoquenessing and glacial deposits from Ellwood City to Ellwood Junction. Although the stratigraphic column resembles the generalized section already presented and described, variations from it warrant further mention. The accompanying sections, Nos. 1-17, (pl. VII) are exposed at the locations indicated on the map (Fig. 3).

Conemaugh group. The Conemaugh group includes all rocks above the Upper Freeport coal, is approximately 210 feet thick, and is represented on the maps (pls. III and IV) by the topmost shaded area. The upper 100 feet show no strata of notable persistence, but consist of vari-colored clay shales and sandy shales, either lumpy or thinly laminated and interbedded with soft sandstones. Below this portion occurs the Brush Creek Rider coal,* recognized only by its blossom, and the Brush Creek coal,* separated from the former by 25 feet of shale or somewhat massive sandstone. The New Galilee clay occurs about 15 feet lower, and the East Palestine coal about 25 feet below that, the intervening strata in both cases consisting of shale or sandy shale. The remaining 50 feet of the formation, usually shows the prominent Mahoning sandstone separated from the East Palestine coal above and the Upper Freeport below by 5 feet of shale, but, locally, is filled entirely with sandstone or with sandy shale. The positions of the coals and New Galilee clay are indicated by appropriate symbols within the shaded area of the map.

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*In the manuscript as submitted the names of these coals were not given. The names here applied solely upon stratigraphic evidence.

Allegheny group. The skeleton section (Pl. VI) shows the positions of the several coals of the group. The intervening sandstones and shales vary greatly in character from place to place. The Upper Freeport-Lower Freeport interval contains the conspicuous Butler sandstone except near Ellwood City where only shale occurs. It has sandstones at the base, except at Bellton, and frequently in the middle; and in the vicinity of Eastvale and Bennett Run the entire interval is filled with sandstone. Between the Lower Freeport and Middle Kittanning coals sandy shale predominates, although, locally, the Freeport sandstone is conspicuous. Between the Middle and Lower Kittanning coals shale usually occurs, as also between the latter and the Vanport horizon. In the neighborhood of Eastvale, however, the Kittanning sandstone, 10 feet thick, lies beneath the Lower Kittanning fire clay and is conspicuous in the cliffs. In section 12, pl. VII, sandstone over the Scrubgrass coal occupies the usual place of the Vanport limestone and its overlying shales. A conspicuous blue-gray sandstone, possibly the Clarion, occurs locally beneath the Scrubgrass horizon in sections 8, 10, 11 and 15 (pl. VII). Where Clarion and Brookville seams are both developed, the interval is mostly filled with shale, and, in the absence of either coal, a sandstone seems to occupy the horizon. Variations of this kind occur near Eastvale.

Pottsville series. The Pottsville series is exposed in a varying thickness, the maximum of 200 feet for this district occurring about one mile below the mouth of Slippery Rock Creek (sections 16 and 17, pl. VII). The series contains the usual members, but correlations are not everywhere clear. Locally, the Homewood sandstone is nearly or quite absent, as shown in section 16, but it usually occurs as a massive conglomerate from 10 to 35 feet thick. A zone of shale, from a few inches to 60 feet thick, separates this from the Upper Connoquenessing sandstone. The shale includes the unimportant Homewood and Mercer coals, 20 to 30 feet apart. The Upper Connoquenessing sandstone varies from 25 to 60 feet thick and is the most conspicuous member of the group. Beneath it, at Thompson Run the thin Quakertown coal and a few feet of shale are exposed (sections 8 and 9, pl. VII). The Connoquenessing section, No. 17, shows a 40-foot interval separating the Upper and Lower Connoquenessing sandstones, and the latter, 20 feet thick, underlain by shale of the Sharon horizon.

Structure.

The structure is mild and therefore favorable for mining. The prominent features are the Homewood anticline, the Blockhouse Run and the North Sewickley synclines, which have already been described. Minor synclinal folds occur near Bellton and North Sewickley. In the southern half of the district the dips are southeastward; in the northern portion they vary in all directions and are best comprehended by reference to the structure contours and the description of their use. Notes on the dips accompany the following detailed description.

DISTRIBUTION OF BEDS, AND LOCAL DETAILS.

This description supplements the map representation and treats first the region tributary to Beaver River or the Beaver River sub-district, beginning at the south, and then the region tributary to the Connoquenessing or the Connoquenessing Creek sub-district, beginning at the north.

Beaver River Sub-district.

Area south of Thompson Run. In this region the dips are predominantly southeastward, away from the Homewood anticlinal axis.

Along the north branch of Blockhouse Run the horizons above the Lower Freeport coal are exposed. At No. 1, just outside the quadrangle, this coal has an altitude of 935 feet, and measures 15 inches (coal section 20, Figure 4). The Upper Freeport is represented ½ mile to the northeast by bituminous shale, at 960 feet altitude. At No. 2 it is 40 feet higher, and is 15 inches thick. Twenty feet higher than the road forks which have an elevation of 968 feet, fire clay fills this horizon. A short distance northwestward, up the dip, the old Phillis bank at elevation 1040 feet was probably on the same bed, although possibly on the East Palestine coal. Half a mile northwestward the blossom of the Brush Creek Rider coal occurs 25 feet above the cross roads, or 1195 feet above sea level. In this neighborhood the New Galilee clay is conspicuous in the relations indicated by section 2 and 4, pl. VII.

East of Beaver Falls excellent exposures occur from near the margin of the map to the mouth of Bennett Run, as shown by sections 1, 3 and 5, pl. VII. The inclination of the strata increases north of Eastvale, and the Homewood sandstone, which is close to railroad level just inside the quadrangle, is 70 feet higher 2 miles northward at an old quarry, No. 11, where it is exposed with the Upper Connoquenessing. There, just above the middle, the 50-foot face shows a horizon of shale and coal streaks which probably represents the Homewood coal. Near the mouth of Trough Run, at the map margin (No. 4) are exposures of the thin Brookville and Clarion coals with their clays. The Clarion measures 20 inches here (coal section 17, Fig. 4), and is 35 feet above the railroad. The Vanport limestone, 25 feet higher, is only one foot thick, and shows cone-in-cone structure. It is separated from the Lower Kittanning fire clay and coal by shale 60 feet thick. Other data from this vicinity follow:

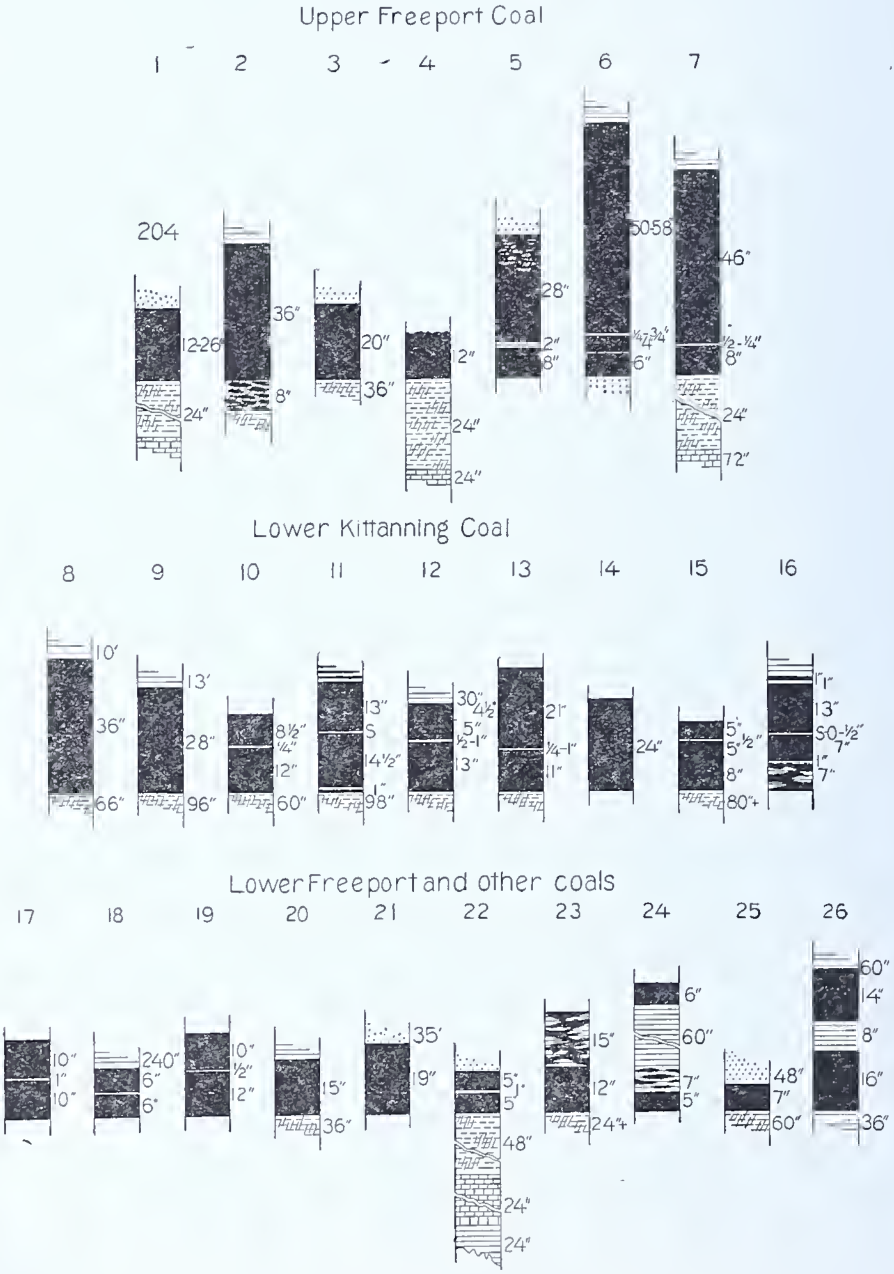

FIGURE 4. Coal sections in southeastern district.

Coals and clays directly east of Beaver Falls.

Map No.	Name of farm or operator	Horizon	Coal			Fire clay
			Altitude	Thickness inches	See figure	Thickness feet
3	?	Lower Kittanning	870±	36	Fig. 4, 8	5½
4	Robertson	Lower Kittanning	870±	28	Fig. 4, 9	8
		Middle Kittanning	915	8*	Fig. 5, 1	
5	?	Upper Freeport	1040			
6	?	Lower Kittanning	930	21	Fig. 4, 10	5+
		Lower Kittanning				
		Middle Kittanning	935	13	Fig. 5, 2	
		Upper Kittanning	955	9		
		Lower Freeport	995	16		
		Upper Freeport	1053	25		
7	J. L. Rowan	Upper Freeport	1065	12—26	Fig. 4, 1	
8	Douglas-Whistler Co.	Lower Kittanning	913	27	Fig. 4, 2	3+
		Middle Kittanning	960	18	Fig. 5, 3	5
		Upper Kittanning	990	7	Fig. 4, 25	
9	George Kirkam	Lower Kittanning	920	23	Fig. 4, 12	
	Frank Smith	Middle Kittanning	960	18		
	Henry Panders	Middle Kittanning	960	18		
	Frank Smith	Middle Kittanning			Fig. 5, 4	8
10	Mumford	Middle Kittanning	970	21	Fig. 5, 5	
11	Stinson	Lower Kittanning	965	21		3+

Water crest at the upper dam is 732 feet above sea level.
* Reported.

The massive Butler and Mahoning sandstones are 20—30 feet thick at the top of the bluffs. The New Galilee clay occurs still higher, rising from an altitude of 1090 feet in the road at the map margin, No. 5, to 1180 feet in the hill north of Eastvale. This clay and thin Conemaugh coals occur conspicuously in the hill road from Bennett Run to Thompson Run mines, and near the head of Bennett Run in section 6, pl. VII. Nearby, (No. 15), the Upper Freeport coal occurs at 1090 feet altitude and is reported to be 44 inches thick, but bony (Fig. 4, 2). Westward, above No. 12, at an elevation of 1105, the same coal was formerly opened. At No. 14, near the school, the Lower Freeport coal is 10 inches thick (Fig. 4, 22) and is 1035 feet above sea level. It also forms a blossom in the road 50 feet higher than the Middle Kittanning at No. 19. The Upper Freeport occurs in the road, 25 feet below the crossing. The Middle Kittanning coal in this valley is 23—34 inches thick, but it contains several partings. Further data are shown by the following table:

Middle Kittanning coal and clay in Bennett Run.

Map No.	Name or operator.	Altitude	Coal Thickness inches	See figure	Fire clay Thickness, feet.
12	Shaffer	995	29		6*
13		970	23½	Fig. 7, 7	6*
19	Thomas	1010	28	Fig. 7, 9	6*
20	Kirkam	1000	23	Fig. 7, 10	1½
21	Kirkam	995	27	Fig. 7, 11	
22	D. P. White	1045	34	Fig. 7, 12	11*

*Reported.

The Lower Kittanning was once opened 42 feet below Mr. White's bank and is reported to diminish from 33 inches near the outcrop to 24 inches under the hill (Fig. 4, 13). The Upper Freeport coal occurs in the hilltop at an altitude of 1150 feet.

In the hollow north of Bennett Run, the Middle Kittanning coal at R. J. Kenney's bank, No. 23, is at elevation 1055 feet and is 34½ inches thick (Fig. 5, 13). Below it, 55 feet, the Lower Kittanning coal was seen 24 inches thick (Fig. 4, 14) in a partial exposure. Near the head of the hollow the Lower Freeport blossom occurs at elevation 1130 feet or 65 feet below the road forks. At Nos. 24 and 25, near the mouth of this run, the cliff shows alluvial clay overlying a sandstone 60 feet thick, which is regarded as the combined Homewood and Upper Connoquenessing (pl. VII, 8). Coal streaks there probably represent the Homewood and Quakertown horizons. Sixty feet above the quarries a road outcrop reveals sandstone, possibly the Clarion, 25 feet thick; this bed is quarried at Nos. 26, 27 and 28, near the mouth of Thompson Run, where sections 9 and 10 (pl. VII) are exposed. At No. 30, in a prospect drift, the Lower Kittanning coal is 18 inches thick and is underlain by 6½ feet of fire clay (Fig. 4, 15). Its elevation, 1015 feet, is 55 feet below the Middle Kittanning bank there and at No. 29, in which it is 14½ and 28 inches thick, respectively, and is underlain by fireclay (Fig. 5, 14-15). The Upper Freeport coal at Thompson Run mines, No. 31, ranges from 12 to 64 inches thick (Fig. 4, 6) and is at elevation 1155 feet. It is overlain by the Mahoning sandstone, which has a 20-foot face at the Kimberly quarries to the north. This underlies the Conemaugh coals and clay.

Area north of Thompson Run. The beds of this area dip northward to a slight syncline near Bellton, then rise to the north and northeast. Two ravines near Bellton offer partial exposures. The one to the south (pl. VII, 12) shows 20 feet of Homewood sandstone at No. 41 and thin coals at the Homewood, Brookville, Clarion and Scrubgrass horizons. The Lower Kittanning coal at No. 40 is reported to be 18 inches thick, and is 45 feet below the Middle Kittanning bed, which was worked at Mr. Mains' bank at elevation 1070 feet. The thickness is 26½ inches (Fig. 5, 20). Because of an eastward rise its elevation is 1090 feet at No. 39, where the Upper Freeport blossom is 130 feet higher and 10 feet below the road corner. Northward 1½ miles, the Middle Kittanning horizon has risen to 1110 feet at No. 46, where it is 24 inches thick (Fig. 5, 23) and is 65 feet below a blossom of the Lower Freeport coal.

Northward from Bellton, the Homewood and Upper Connoquenessing sandstones underlie the terrace deposit of clay and boulders; and the latter sandstone is quarried at No. 49. Above the terrace a thick development of the Vanport limestone occurs below No. 48, its top lying 85 feet above the road, or at elevation 1000 feet. The Middle Kittanning there is at elevation 1090 feet and is 24 inches thick (Fig. 5, 25). At J. P. Rouser's, No. 47, it is 22 inches (Fig. 5, 24) at elevation 1110 feet, and is 80 feet above the limestone. The Lower Kittanning coal is reported to be 18 inches thick about 50 feet below the Middle Kittanning bed. The Lower Freeport blossoms in the road to the northeast at elevation 1160 feet.

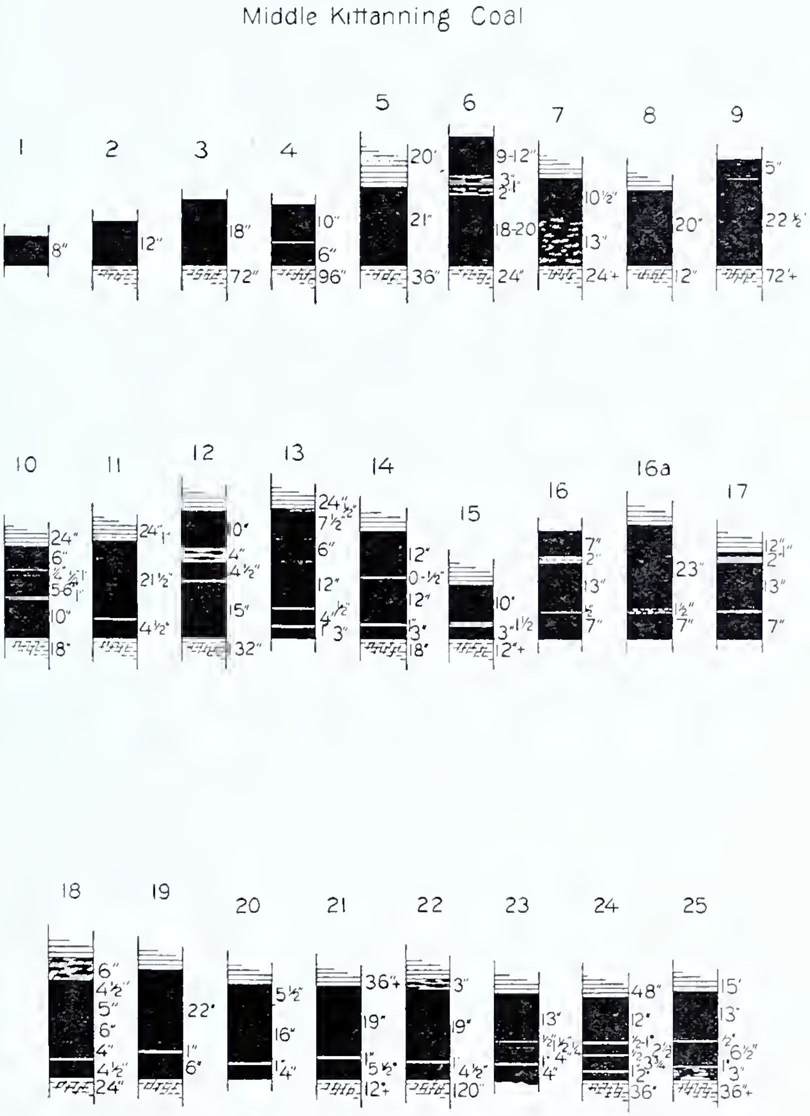

FIGURE 5. Coal sections in southeastern district.

Connoquenessing Creek Sub-district.

The Upper Connoquenessing sandstone forms the top wall rock from the mouth of Connoquenessing Creek to Wurtemburg, and at quarries Nos. 52, 53, 55, and 56 shows workable faces of about 40 feet. Section 17, pl. VII, was obtained just east of Ellwood City.[40] The sandstone descends both to the east and to the west from the anticlinal axis. The strata of the Homewood horizon are shaly there, although massive in the district to the north. Ellwood City is on a rock terrace capped by clay deposits which extend southeastward up the valley of Connoquenessing Creek to the edge of the map, and which are exposed at the brick yards, No. 54. South of the town there are three openings on the Middle Kittanning coal. At No. 50 the coal is at elevation 1085 feet and is reported to be 36 inches thick. The Vanport limestone lies 90 feet below it, and 80 feet above the road. At No. 51 the coal is at altitude 1080 feet. The Lower Kittanning and Vanport outcrop to the northward at elevations 1035 and 1010 feet respectively. At Charles Blank's bank, No. 45, the Middle Kittanning coal is 27½ inches thick (Fig. 5, 22) and 1095 feet above sea level. This is 75 feet above an old quarry on the Vanport limestone, and 75 feet below a blossom of the Lower Freeport coal in the hill road. Section 16, pl. VII is exposed there, and section 14 a little farther south. Between them the Vanport thins and perhaps entirely disappears. The opening at No. 42, at 1030 feet altitude, is perhaps on the Clarion seam or the Lower Kittanning (Fig. 4, 19). The Middle Kittanning was once opened 80 feet above it. The Lower Mercer coal at Wurtemburg, No. 57, is reported to have top and bottom benches, 14 and 16 inches thick respectively, and 8 inches of shale between them (Fig. 4, 26).[41] The limestone is thin east of Connoquenessing Creek from Wurtemburg toward North Sewickley, and to the southeastward. Below it several blossoms occur at the horizons of the Scrubgrass, Clarion and Brookville coals.

The Lower Kittanning coal and clay blossom was observed 40 feet below the Middle Kittanning at No. 44, where the latter is at elevation 1070 feet and is reported 27 inches thick. The same coal at Mr. McKimm's bank, No. 43, is 30 feet lower in altitude and measures 25½ inches (Fig. 5, 21). Section 15, pl. VII shows the stratigraphic conditions in this vicinity.

One mile southwest of North Sewickley where section 13 occurs, the Middle Kittanning coal is again prominent. At Fred Miller's bank, No. 38, it is 29 inches thick (Fig. 5, 19) and is at altitude 1030 feet. On the Collins Place (No. 37) it is 31 inches thick (Fig. 5, 18), and is at elevation 1040.

To the westward an abandoned prospect hole indicates that this coal rises in that direction. It probably lies above the coal shown at No. 35, at elevation 1030 feet, which is 30 inches thick (Fig. 4, 16), and is regarded as the Lower Kittanning. Near the mouth of the run at this locality the Vanport limestone occurs at 905 feet altitude and is one foot thick. Westward in the hill the Middle Kittanning coal is 75 feet higher and maintains this elevation to the bank at No. 34, where the coal is 23 inches thick (Fig. 5, 17). In the road above, blossoms of the Lower and Upper Freeport beds occur respectively at 1090 and 1140 feet altitudes. Eastward at No. 33, the Middle Kittanning coal is 30-31 inches thick (Fig. 5, 16, 16-a) and 985 feet above sea level. At the mouth of Brush Creek, No. 36, the Clarion coal is 12 inches thick near water level (Fig. 4, 18). At the map margin occurs section 11, shown on pl. VII. This includes strata between the Clarion (?) sandstone and a horizon 40 feet above the New Galilee clay. Farther west, at No. 32, the bank of Mr. Hermann shows the Upper Freeport coal 54 inches thick (Fig. 4, 7) at approximately altitude 1110 feet. A southeast dip makes its elevation 1095 feet at No. 18, on the Brandenberger farm, where the coal is 38 inches thick (Fig. 4, 5). Near the edge of the quadrangle, at No. 17, the Upper Freeport is partly exposed in an old coal bank. The underlying limestone and 12 inches of the coal were seen (Fig. 4, 4). Half a mile farther east a small bank shows 20 inches of coal (Fig. 5, 8) 15 feet above the road corner, or 915 feet above sea level. This is probably the Middle Kittanning coal, as a bed 20 feet lower is said to occur a short distance to the north. At No. 16, exposures show the Upper Freeport bed 20 inches thick on 3 feet of fire clay (Fig. 4, 3). It is at altitude 1050 feet and has above it the Conemaugh beds, shown in section 7, pl. VII, which occur also from this point to the southeastern corner of the district.

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[40] Pennsylvania Second Geol. Survey Rept. QQ, p. 97.
[41] Pennsylvania Second Geol. Survey, Rept. QQ, p. 75

ECONOMIC SUMMARY, SOUTHEASTERN DISTRICT.

The following paragraphs summarize the detailed notes on coal, clay, shale, limestone and building stone in the southeastern district.

Coal.

This district has three exposed coals of known value, the Upper Freeport, Middle Kittanning, and Lower Kittanning. In addition to the foregoing there are 12 other exposed coal horizons, in a vertical interval of 500 feet. Three of these which are locally valuable in other parts of the quadrangle may ultimately add to the resources of this district. The beds offering this possibility are the East Palestine, Lower Freeport, and Upper Kittanning. The following description of the coals is supplemented on later pages by analyses and mining notes which in part apply to this district.

Upper Freeport coal. ("Thompson Run coal"). The section on Fig. 4 show the thickness and structure of the Upper Freeport bed at the localities indicated on the map. Normally, the coal is 4 to 5 feet thick and is separated from the overlying Mahoning sandstone by shale 1 - 6 feet thick, and from the underlying limestone by fire clay 1 - 3 feet thick. These conditions are favorable for mining. Abnormal conditions often occur, however, and over considerable areas the Mahoning sandstone descends into the horizon of the coal, partly or entirely cutting out the latter bed. Thus, in the Thompson Run mine, No. 31, the coal is workable for over a mile in an east-west direction, but its thickness diminishes to 12 inches within ¼ mile to the north.

The accompanying coal sections indicate thickness ranging from 12 to 64 inches. Locally, the coal is absent, although it is said to be 6 feet thick in parts of the mine mentioned. The quality of the bed is excellent except for impurities which usually lie near the base of the normally developed coal. A persistent clay band, a quarter of an inch to 2 inches thick, occurs 8 to 10 inches above the floor, and beneath this the coal is sulphurous and bony, and usually is not mined.

The area underlain by the horizon of this coal is suitably indicated on the map. Its altitude can be determined at the outcrop by reference to the topographic contours, and within the outcrop by calculations based on the Middle Kittanning structure contours.

Although the area included within the line of outcrop is about 7,700 acres, it is useless to attempt to estimate the total area underlain by workable coal, because the variations in thickness are local and of major importance, and are only determinable by close drilling or other prospecting. Present data indicate that the probable extension of the workable area is eastward from the Thompson Run mines and southeastward towards the corner of the district.

Middle Kittanning coal. The accompanying sections (Fig. 5) indicate the thickness and structure of the Middle Kittanning coal observed or reported at the localities shown on the map by numbers. As a rule the bed is 24 - 28 inches thick, and has a shale roof and fire clay floor suited to easy mining. Locally, however, the bed loses its commercial value because of diminution in thickness of the coal or increase in the amount of impurities.

The coal sections indicate thicknesses ranging from 8 to 34 inches. These apply to measurements near the outcrop, however, and only in a general way suggest conditions in the interior of the area. Along the outcrop bordering Beaver River, the coal thickens from 8 inches at the margin of the map to Bennett Run where it reaches 27 - 34 inches. Measurements elsewhere indicate mineable thickness, with the exception of a local thinning to 14½ inches on the south side of Thompson Run, at No. 30, and a thickness of 20 inches just beyond the east margin of the district.

Where the coal is thin the bed is unbroken by partings, but where thick, one or more partings appear to be somewhat persistent. One of clay or shale 1 inch thick or less, commonly occurs at 3 - 7 inches above the floor in the observed sections north of Bennett Run. Three clay bands ¼-1 inch thick occur within 12 inches of the floor in banks 46 and 47, east of Ellwood Junction. Another combination of shale or clay and coal stringers occurs about 20 inches above the floor in sections observed in Bennett Run and those about 3½ miles to the northeast. These impurities, where observed, ruin 2 - 6 inches of the bed, and are reported to be 18 inches thick, locally, in Mr. Shaffer's mine, No. 12, south of Bennett Run. West of this bank an unverified report states that this coal is split into two benches by shale 8 feet thick. Such condition suggests the section of the Upper Kittanning coal observed east of Beaver Falls, at No. 6, (Fig. 4, 24). Although the presence of bands in the Middle Kittanning coal detracts greatly from its value the remainder of the bed is excellent, and mining on a large scale would doubtless be profitable throughout this district, as it is elsewhere in the quadrangle under similar conditions.

The position of this bed is indicated by its line of outcrop, on the map, and by the structure contours. The total area underlain by its horizon is approximately 10,900 acres. The bed is not workable under all this area, but probably it is generally workable in the portion north of a line projected through mines Nos. 12 and 33, which area is about 5,400 acres. Southeast of this line, also, the coal may, on further investigation, prove valuable.

Lower Kittanning coal. Coal sections on Fig. 4 indicate the thickness and structure of the Lower Kittanning coal at the localities shown by numbers on the accompanying map. Its condition is imperfectly known, however, because of lack of evidence. Judging from exposures in country banks and along ravines and road cuts, the bed is usually overlain by shale and underlain by thick and valuable fire clay.

The coal sections indicate thicknesses ranging from 36 inches just beyond the south corner of the district, at No. 3, to 18 inches at Thompson Run, No. 30. The same thickness is reported near Ellwood Junction at Nos. 47 and 40. Farther east, at No. 35, a coal, probably the Lower Kittanning, is 22½ inches thick, and at No. 42, where also its identity is doubtful, it appears to be 30 inches thick. The coal is free from persistent bands although several sections show a sulphurous clay parting 1 inch thick or less, located 11 - 14 inches above the floor. At No. 35 the bed has bands which suggest the Middle Kittanning. The coal is marketable but it contains more sulphur than the bed above and is not in such high favor.

The area underlain by the Lower Kittanning coal is appropriately shown on the map. Its altitude can be determined by reference to topographic contours and the structure contours on the Middle Kittanning bed. The area under which the coal is of mineable thickness cannot be stated.

Other coal beds of possible value. The other coal beds most likely to prove locally valuable either alone or in connection with those already described are the East Palestine, Lower Freeport, and Upper Kittanning, although the probabilities are that all are worthless.

The horizon of the East Palestine coal bed is indicated on the map at several points between the outcrops of the Upper Freeport coal and the New Galilee clay. Drilling may demonstrate its workability in connection with the Upper Freeport coal where it alone could not be handled commercially. This is the "Three-foot" or "Red Hill" coal, worked along the west margin of the quadrangle in Darlington Township.

The Lower Freeport coal locally may prove workable in connection with the Upper Freeport or one of the Kittannings. Within the southeast district its sections range from 10 to 19 inches thick (Fig. 4), and its blossom is shown at numerous places on the map, indicating a wide persistence. The thinness of the coal is due in many places to descent of the overlying sandstone, similar to that of the Mahoning sandstone over the Upper Freeport coal. This fact makes it seem probable that locally the Lower Freeport bed may prove valuable, as it is well developed near New Galilee and Mountair.

The Upper Kittanning coal was observed as a thin worthless bed at Nos. 6 and 8. In Trough Run, northeast of No. 4, however, it occurs as a slaty cannel. Inasmuch as it is often a local cannel coal of good grade, as at Cannelton and at numerous other localities in the areas bordering this quadrangle, it may ultimately be found workable here.

Clay and Shale.

This district offers a variety of materials suitable for the manufacture of refractory, structural and domestic ware. Refractory and stoneware clay is obtainable from the Lower Kittanning horizon and possibly from beneath several other coal beds. Excellent paving or building brick can be made from various combinations of fire clay, shale, and terrace clay. The following notes are supplemented on later pages by descriptions of methods used throughout the quadrangle to obtain and prepare clay materials.

Fire clays.

Lower Kittanning fire clay. The Lower Kittanning fire clay is perhaps the most valuable mineral resource of this district and warrants thorough testing where advantageously situated with respect to transportation facilities. Its thickness and character were observed at five openings as shown by the table on p. 75. Elsewhere it is known only from its frequent wide white blossoms in the roads. It is probably valuable at many places along its outcrop. At the Douglas-Whisler Company mine at Eastvale (No. 8) the clay section resembles that seen elsewhere in the quadrangle. The upper three feet is soft and plastic, the next lower two feet harder and grading at the base into a more siliceous portion which ranges between 1 and 3 feet thick. These combined average 6 - 8 feet thick and constitute the commercial part of the bed. Separating this from the Kittanning sandstone is a worthless siliceous clay 1 -3 feet thick, which contains numerous "iron balls." When fresh, the clay is uniformly drab to gray in color and shows irregular structure. When exposed it becomes somewhat darker; in about two months it disintegrates to a fine powder of great plasticity.

Other clays of possible refractory value. Each of the clay horizons shown in the stratigraphic sections may locally offer material which is valuable alone or in connection with the Lower Kittanning clay; and because of their known or probable value in adjoining regions the most promising are the Clarion, Middle Kittanning, Lower and Upper Freeport, East Palestine and New Galilee clays.

The Clarion clay occurs in numerous blossoms beneath the coal at the localities to which references have already been made. South of Ellwood City, at No. 42, a coal 22 inches thick, possibly Clarion, has a white siliceous under-clay of promise.

The Middle Kittanning clay is prevailingly somewhat ferruginous, but locally it may prove valuable. Where measured it ranged from 3 to 6 feet thick and, according to report, it is 11 feet thick in Bennett Run. Flint clay occurs at this horizon opposite Beaver Falls (No. 6), at the Douglas-Whisler property (No. 8), also in the road above Eastvale at the bank of D. P. White in Bennett Run (No. 22), and below the schoolhouse at No. 34.

The Lower Freeport clay is 3 and 4 feet thick, respectively, at Nos. 1 and 3, and commonly makes conspicuous white blossoms in the roads.

The Upper Freeport clay is 1 - 4 feet thick in the coal openings of the district, and is more persistent than the coal itself. Flint clay, observed just below this horizon in section 11, pl. VII, probably represents the famous "Bolivar" clay.

The East Palestine clay underlies that coal at the localities where outcrops are noted on the map, although its character and thickness are not revealed.

The New Galilee horizon shows a flint clay which locally looks valuable, though more commonly severely stained with iron. It may be easily exposed by slight stripping on the hilltops.

Alluvial clay.

Alluvial clays cover the rock terraces near the mouth of Bennett Run, near Bellton, and along Connoquenessing Creek at and above Ellwood City. As seen in the district these were at least 25 feet thick. At the plant of the Ellwood Brick Company (No. 54) 15 feet of buff silt with occasional pebbles overlies blue-gray sandy clay 10 feet thick, and both are used in manufacture of soft red building brick. A mixture of these clays with fire clay or shale would probably give harder brick of several colors, or could be worked into flower pots or terra cotta.

Shale.

The shales used with fire clay in making building brick at the Douglas-Whisler plant (No. 8), occur at two horizons, one probably between the Brookville and Clarion, and the other just above and below the thin Vanport limestone. These beds are respectively 10 and 30 feet thick, and their use produces buff, red or black brick of excellent quality.

Doubtless these shales and others shown in the stratigraphic sections, either alone or with the addition of another clay, are suitable for paving brick. The Allegheny formation offers such shales at numerous horizons. The Conemaugh shales probably are usable to some extent, but they are out of reach of convenient railroad transportation. They might be worked as an auxiliary to some other economic resource.

Sandstone.

Sandstone occurs at many geologic horizons in this district and is naturally suited for heavy construction work and curbing; or, after crushing, for engine sand and possibly glass sand. Thirteen commercial quarries were either active at the time of examination or had been recently and temporarily shut down. One of these, as shown by the following table, is on the Mahoning sandstone, but the others are on the Clarion, Homewood, and Upper Connoquenessing beds, which lie conveniently with respect to the main transportation lines. Other beds which are of value, locally, are the Butler, Freeport and Kittanning sandstones, shown in the columnar sections. Notes on quarry methods used in the quadrangle are given on a later page.

Upper Connoquenessing sandstone. The Upper Connoquenessing sandstone offers dimension stone of good size and quality which, when crushed, would also make engine sand and possibly glass sand. Thicknesses as great as 60 feet are exposed in quarry faces. The bed is a hard, massive or thick-bedded stone composed of angular quartz grains of medium size which are cemented with silica. Locally, it is irregularly or cross-bedded and contains fragments of fossilized tree trunks, as at No. 11. The rock is notably free from iron, and is usually white or gray in color, although in places it is tinged with yellow.

Homewood sandstone. The Homewood sandstone, which, in this district, is commonly separated from the Upper Connoquenessing by a few inches or feet of shale or "leaders" of coal, is worked either alone or with the underlying rock, and yields dimension stone and curbing. Its thickness is as much as 35 feet in natural exposures, but in present quarries it is only 20 feet thick. It is composed of coarse, rounded quartz grains, although locally it contains white pebbles up to a quarter of an inch in diameter. The cementing material is silica; some iron is also present. Commonly its color is cream, but it may be yellow or rich brown.

Clarion sandstone. The thinly laminated micaceous sandstone which, in this district, overlies the coal presumed to be Clarion, locally becomes sufficiently massive to furnish dimension stone. Where well exposed it is about 20 feet thick. It consists of very fine grains of quartz and occasional flakes of white mica apparently cemented with silica. Its color is a conspicuous light blue gray.

Mahoning sandstone. The Mahoning sandstone offers 20 to 30 feet of coarse quartzose rock suitable for dimension stone and curbing. It is massive or thick-bedded where well exposed, and consists of quartz and occasional mica flakes cemented with silica and a considerable amount of iron. In color it ranges from white to yellow. The stone is soft and easily cut in all directions, yet hardens on exposure; hence well warrants development where transportation facilities are good. It could be readily worked in connection with the underlying coals and clays, for its situation on the hill tops offers easy stripping.

Quarries in the district. The following table presents general notes on the quarries in the district:

Sandstone quarries of Southeastern district.

Map No.	Name of operator or quarry.	Character of shipments.	Name of bed.	Thickness feet.
11	Unknown	Dimension stone	Homewood and Upper Connoquenessing	50
24	J. Moscarelli	Dimension stone and curbing	Homewood and Upper Connoquenessing	20
25	Gwinner No. 1	Dimension stone and curbing	Homewood and Upper Connoquenessing	45
26	Craig and Morrow	Dimension stone and curbing	Homewood and Upper Connoquenessing	--------
27	Unknown	Curbing	Clarion	35
28	Lewis Lorenzi	Curbing	Clarion	15
31	Kimberly Stone Company	Curbing	Mahoning	20
41	Unknown	Dimension stone	Homewood	25
49	Skillen	Dimension stone and curbing	Upper Connoquenessing	15
52	Clydesdale Stone Company	Dimension stone and curbing	Upper Connoquenessing	60
53	Ellwood Stone Company	Dimension stone and curbing	Upper Connoquenessing	40
55	Unknown	Curbing	Upper Connoquenessing	10+
56	French	Curbing	Upper Connoquenessing	40

Limestone.

Limestone for Portland cement, furnace flux, lime, concrete, and road ballast is probably available in this district, although analyses are not at hand to prove its suitability for the first two products. The limestones occur at three horizons: the Vanport, and the Lower and Upper Freeport.

Vanport limestone. Thick development of the Vanport limestone appears only in the northern part of the district near Ellwood City and Wurtemburg. Southward this limestone is only a foot or so thick and, locally, it is probably absent. There is a considerable quantity of this bed available beneath moderate stripping. The following table summarizes observed thicknesses.

Vanport limestone in Southeastern district.

Map No.		Thickness	Remarks.
44		5+	Wurtemburg to North Sewickley.
45	(Sec. 16)	25±	
45		18	Old quarry.
47		10	
48		14	6 feet concealed in middle.
50		5	
51		12	

Freeport limestones. The positions of Upper and Lower Freeport limestones, which usually occur beneath their respective coals, may be judged by reference to the map and the coal notes. They are thought to offer only impure ferruginous stone of slight economic value. Lime of fairly good quality has been made from either bed, but with difficulty.

SOUTH CENTRAL DISTRICT.

GENERAL STATEMENT.

The South Central District extends westward from Beaver River to Little Beaver Creek. The extreme northwestern boundary is an irregular line joining the mouths of Beaverdam Run and Jenkins Run. The district consists of Big Beaver and parts of South Beaver and Chippewa townships in Beaver County; the smaller townships and boroughs in the vicinity of Beaver Falls; and, in Lawrence County, nearly all of Big Beaver and the extreme southeast corner of North Beaver townships. It is an upland area rising 500 feet above the Beaver, but it is deeply cut by minor stream valleys and is bordered on the east and west by conspicuous terraces and alluvial flats. Railroads follow the flats and cross the upland divide only at the "Summit Cut" of Big Beaver township. Minor railroad spurs, however, follow the ravine near Wampum and formerly were also utilized at Hoytdale and Stockman Run as outlets for the coal resources of the district. The general upland area furnishes coal and fire clay, and, near Wampum, limestone for cement, flux, and lime. The bluff along Beaver River offers great quantities of massive building stone. The production of oil and gas is described on later pages.

GENERAL GEOLOGY.

Stratigraphy.

The rocks exposed are water-laid sediments along the terraces and flood plains of Beaver River and Little Beaver Creek, glacial debris on that part of the uplands lying north of the glacial boundary indicated on Plate II, and consolidated Carboniferous strata about 755 feet thick occurring in the Conemaugh, Allegheny, and Pottsville groups. The Conemaugh beds are those from the roof of the Upper Freeport coal upward to a horizon about 100 feet above the New Galilee clay,—thus including 180 feet of strata. They are exposed on the uplands, the highest beds occurring two miles east of Darlington. The entire Allegheny group, 325 feet thick, is exposed in the hill slopes and ravines along Beaver River; but only the upper 180 feet of this group is above drainage along the Little Beaver. The upper limit of the Pottsville group is the massive sandstone of the

Beaver valley. The group includes the rocks from this stratum downward 250 feet to a horizon 90 feet below the Quakertown coal, as exposed east of Homewood at the mouth of Clarks Run.

The character of the stratigraphy is indicated by the columnar section, Plate VI, supplemented by the local detailed sections shown on plates VIII and IX. The general stratigraphic description on earlier pages will prove helpful in the study of this district. The coals and limestones serve as the best horizon markers, and all of these are represented except possibly the Clarion bed; but the Lower Freeport and Upper Kittanning coals and the Vanport limestone are markedly irregular in their distribution. The intervals between the coals are occupied by beds which vary in lithologic character within short distances. For example: between the Upper Freeport limestone and the Lower Freeport coal, only sandstone may be present, as at Beaver Falls; or only shale, as in the middle of the district along a line from Stockman Run, through the "Summit Cut" to the southwest corner of the area. Or, again, exposures may show the lower strata to be shale, as along the west edge of the district; or sandstone, as at Wampum. The beds between the Lower Freeport limestone and the Upper Kittanning coal are commonly sandy shale, there being but 15 feet of the Lower Freeport sandstone lentil exposed locally. Another even more extreme variation occurs in the case of the Vanport limestone which is 22 feet thick at Wampum, but thins just north of Possum Hollow, and, at that place, is represented by one foot of sandy limestone. No other exposures occur north of Morado, but near this place, in Wallace Run, the bed is probably represented by a sandy limestone 18 inches thick. As revealed in the ravines south of Beaver Falls, the Vanport is harder and purer, but again only 18 inches thick; but three miles farther south, at Fallton, it measures 10 feet. In parts of this district, away from Beaver River, the horizon of the Vanport has not been reached by streams and its occurrence has not been noted in records of deep wells.

Below the Vanport, the stratigraphy is too variable for description in general terms. The Pottsville group is irregular and its correlations uncertain. The best of the exposures are represented graphically, (plate VII), and detailed description is presented on pages 47-57, and 113. The chief features are the heavy sandstones and conglomerates separated by shales and thin coals and limestones,—or frequently combined, to the exclusion of the intervening beds.

Structure.

As indicated by the structure map and the cross section fig. 2, the Homewood anticline extends southwest across a portion of this district. Its crest is relatively broad and flat, but on its southeast flank the beds dip toward Beaver Falls at a rate of about 50 feet per mile; and on the northwest, toward the axis of the Darlington syncline at a slightly gentler and less regular rate. In South Beaver Township, the anticline is broken by two minor spurs which lead northwestward and are separated by a mild syncline. In the northern part of the district, the beds dip from the northwest, about 20 feet per mile, into the Darlington syncline. Where mining has been extensive numerous minor structural hills have been revealed. These are in part due to unequal deposition, rather than folding. It is well established that dips are relatively mild and offer no great obstacles to mining.

DISTRIBUTION OF BEDS, AND LOCAL DETAILS.

For convenience in description the district is divided into four sub-districts as indicated on fig. 3. Within the area occur stratigraphic sections 33 to 45 inclusive, plate VIII and 55 to 66 inclusive, plate IX, as well as locality numbers 200 to 362 inclusive and 491. The coals of the district are illustrated by Figs. 6, 7 and 8.

South Beaver Sub-district.

Area south of Brush Run. Proceeding eastward from the southwest corner of the sub-district, data were obtained along the margin by L. H. Woolsey during his survey of the Beaver quadrangle. At Mr. Davidson's bank, No. 200, the Upper Freeport, or "Four-foot" coal was once opened at elevation about 1045 feet. Across the creek to the north, its blossom in the road is 20 feet higher. Eastward on the Elton farm, No. 201, the same bed occurs 30 - 41 inches thick with the Mahoning sandstone above and the usual limestone below. The altitude is about 1045 feet. Fifty-five feet lower, the Lower Freeport is 30 inches thick and has below it 3 feet of clay and a limestone 9 feet thick. The Upper Freeport was also worked on the Cowan farm to the east, No. 202, about 1040 feet above sea level and is reported to be 41 inches thick. From this locality there is a sharp eastward rise of the beds. At No. 203, the Upper Freeport is at elevation of 1055 feet; at No. 212 the elevation is 1105 feet; and eastward where section 60 occurs the elevation of the coal is 1115 feet. The Upper Freeport coal there is reported by Woolsey to be 56 inches thick but full of "horsebacks." The Lower Freeport, 60 feet lower, is said to be 34 inches thick. The Middle Kittanning, known as the "dirt vein", here and at No. 214 is reported to be 4 feet thick with a 10-inch clay parting in the middle. The Lower Kittanning is said to be 2 feet thick and is at elevation 980 feet. In the roads along the valley the massive to shaly Kittanning sandstone is exposed 10 - 20 feet thick.

The dips in this vicinity are indicated by the varying elevations of the coals. The elevations of the Middle Kittanning are 1005 feet at No. 213, 1015 at No. 215, and 1040 at No. 214. The Lower Kittanning at No. 213 is at altitude 980, and at the blossoms at Nos. 216, 217 and 218 is 990, 1015 and 1025 respectively. The elevation of the Upper Freeport is 1115 feet at section 60 and 1150 feet at a blossom and old bank below Mr. Reed's house, No. 220. Data obtained since the publication of reports on the Beaver quadrangle have resulted in a slightly different interpretation of the structure and correlations along the map margin from No. 213 to No. 220; but the stratigraphy of the region is obscure and considerable uncertainty still remains. The influence of the dips on the accumulation of natural gas is presented on a later page.

Additional data south of Brush Run are offered by outcrops and coal openings farther north. Near the State line at No. 206, an old opening and coal blossom, thought to be the Lower Freeport, occur 160 feet above the creek or 1000 feet above sea level. Sandstone debris covers the surface for 60 feet below, and at altitude 915 feet the Middle Kittanning is represented by a blossom. Shale occupies most of the interval to the creek, concealing the horizon of the Lower Kittanning. Eastward, however, at No. 208, its blossom is at elevation 875 feet. The Upper Freeport outcrops 160 feet higher at No. 207, and the East Palestine coal lies 55 feet above the latter, at No. 205. The bed dips slightly eastward, for, at an old bank at No. 204, its elevation is 1035 feet; thence it rises eastward and is at 1055 feet at No. 211.

Area draining from the north to Brush Run. South of the divide which separates Brush Run from Little Beaver Creek, road exposures occur along the hilltop and along the slopes and ravines leading southward. Section 55 (pl. IX) indicates the stratigraphic column near the State line. There the Middle Kittanning coal is reported to be 18 inches thick. It makes conspicuous blossoms 35 feet above the Lower Kittanning bed and 925 feet above sea level. Another excellent exposure, section 58, (pl. IX), occurs to the eastward, with the various beds 10 feet lower than in section 55. Eastward another mile, the Lower Kittanning at No. 209 occurs 20 feet above the road corner or 880 feet above sea level. At a level 120 feet higher, the Lower Freeport coal is opened at No. 210 and is 21 inches thick (Fig. 6, 16). A road blossom 50 feet lower probably represents the Upper Kittanning bed. In the road leading north from No. 209, the Upper Freeport blossom is 145 feet higher than the Lower Kittanning and appears to have dipped 15 feet from its position in section 58. Above it 55 feet, or at altitude 1080 feet, the East Palestine coal occurs. This rises 10 feet in passing northeastward to No. 263. Along the hill road 35 feet above it, the New Galilee clay outcrops,

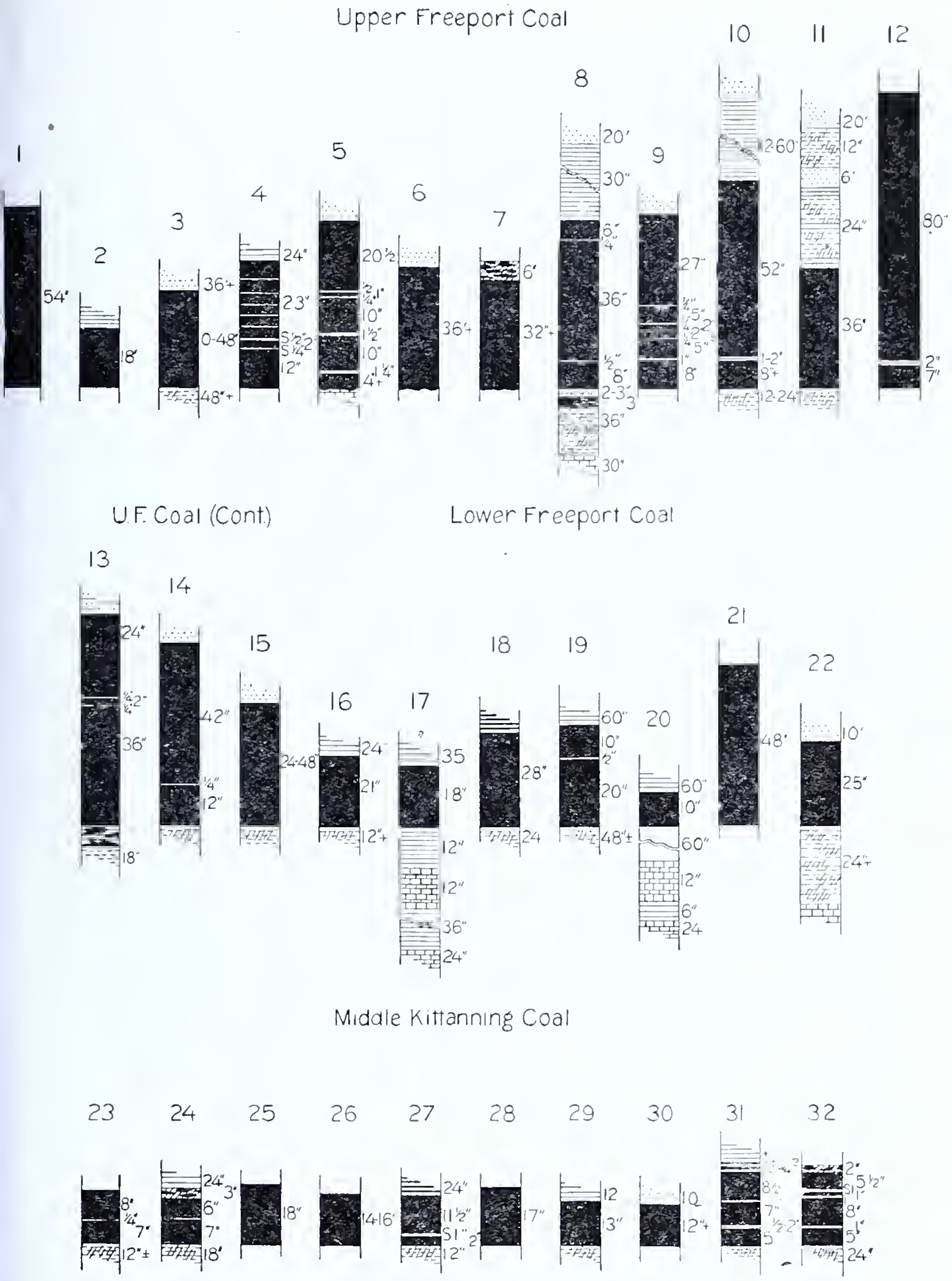

FIGURE 6. Coal sections in south central district.

while eastward the Upper Freeport coal at No. 262 is at the level of the road forks, or 1065 feet above sea level. A dip in that vicinity is indicated by changes in altitude of the Upper Freeport coal; its altitude at No. 262 and No. 259 is 1065 feet; at No. 260, 1080, nearby 1095, and at No. 258 farther east, 1110 feet. In that locality, the

Lower Freeport occurs 35 - 45 feet below the upper bed. The Mahoning sandstone there is 25 or more feet thick, but is disintegrated into sand along the roads. In section 59 (pl. IX) an interval of 175 feet occurs between the Upper Freeport and the Lower Kittanning coals, but, in the road to the northeast, this interval appears to be 50 feet less because of the steep northwest dip shown by the structure contours. In both sections, as elsewhere to the east and south in this vicinity, the Kittanning sandstone is prominent.

*Area tributary to Little Beaver Creek, west of Painters Run.** Exposures from the New Galilee clay horizon to below the Kittanning sandstone occur there, as indicated by sections 56 and 57 (pl. IX). The Lower Freeport at No. 264 is at elevation 970 feet. It is about 36 inches thick. The Upper Freeport limestone is exposed 50 feet higher with fragments of its overlying coal. Section 57 offers no exact measurements of the coals except that at the base, which is projected into the section from its outcrop to the west in the railroad cut, No. 372. It is 9 inches thick and may be the Scrubgrass coal. Southward at No. 266, the Lower Freeport blossom occurs just below the road level or at elevation 960 feet. The Upper Freeport blossom in the road to the north is 60 feet higher, and, southward at the Creighton bank, No. 265, that coal is at altitude 1035 feet, and is 38 inches or more thick (Fig. 6, 7). Mr. Jackson's bank in this vicinity shows 55 to 60 inches of coal (Fig 6, 8).[42] A steep northwest dip is indicated by the elevation mentioned and by those of the same bed to the eastward, where it is 1065 feet at No. 262 and 1080 feet at No. 260. The same altitude obtains in a bank at No. 261 where the bed is 3 feet thick in an incomplete exposure (Fig. 6, 6). Northward, the Lower Freeport blossom is 20 feet lower, or 1060 feet above sea level. Farther north on the James Elder place, No. 267, this bed is probably represented at a spring at altitude 1020 feet, although this is locally regarded as the "Four-foot" or Upper Freeport. The Lower Kittanning coal was opened by Mr. Elder at No. 268 and is reported to be 40 inches thick and underlain by fire clay about 8 feet thick (Fig. 7, 64). The bed rises from its elevation 895 feet there to the outcrops at Cannelton. Upstream from the Elder farm, Painters Run valley is covered by alluvial deposits which conceal rock outcrops. At its head on the Kirchgessner farm, No. 257, the Middle Kittanning coal blossom is in the stream at elevation 1010 feet. The Lower Freeport limestone occurs 70 feet higher to the westward. Near Brush Run, at No. 217, the Kittanning sandstone is prominent and the Lower Kittanning coal lies over it in the road at elevation 1015 feet.

Area east of Painters Run. Near the southern limit of the quadrangle, at the Reed farm, No. 220, as already stated, the Upper Freeport blossom is 1150 feet above sea level or 65 feet below the road forks. At No. 221 and northward to Saints Rest School, the New Galilee clay is exposed. Westward at No. 219, 65 feet below the school road corner, or 1160 feet above sea level, an old opening was probably on the Upper Freeport coal; and a limestone, outcropping 30 feet higher there and also seen in the road north of the school, is at the East Palestine horizon. The Upper Freeport coal outcrops at the road forks, No. 256, under the Mahoning sandstone, at elevation 1146 feet. It is at the same level in the road to the westward, where it is 50 feet above the Lower Freeport blossom. To the northward, at No. 273, the Upper Freeport is 10 feet below the road corner, or at elevation 1125 feet, and the lower bed is only 30 feet lower in the three ravines to the west. At No. 272, the Lower Freeport has descended to 1055 feet. Its blossom in the road at the hilltop, No. 269, is at the same elevation. Two old openings in the intermediate area, Nos. 271 and 270, are at altitude 980 feet above sea level and represent either the Upper or Middle Kittanning horizon. At the northern bank, blocky coal 36 inches thick is reported.

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*For a description of coal stripping operations in this area see pages 159-163.

[42] Pennsylvania Second Geol. Survey, Rept. Q, p. 239.

Near Darlington, the Lower Kittanning coal and fire clay are mined at No. 297 by the Darlington Brick and Mining Company. There the coal is 27 inches thick (Fig. 7, 70), and is at elevation 930 feet. The fire clay is four feet thick or more. The Middle Kittanning is represented there by a clay 25 feet higher. South of town, section 62 occurs (pl. IX), showing elevations of 1115 and 1070 feet respectively for the Upper and Lower Freeport coals, and 930 for the Lower Kittanning. The latter coal is at 945 feet elevation at the old bank to the eastward, No. 294, but is 10 feet lower at Mr. Lightfoot's bank, No. 295. There the bed is 32 inches thick (Fig. 7, 68), and is reported to overlie 4 feet of soft, and 12 feet of hard, siliceous fire clay. The coal rises to the southeastward and southwestward and at No. 296 is 945 feet above sea level and 28 inches thick (Fig. 7, 69). Upstream, the Middle Kittanning, at No. 274, is 40 feet above the road corner, or at altitude 1,000 feet. At No. 275, on the Ferguson farm, a cannel coal, probably the Upper Kittanning, is reported below the road, or about 1025 feet elevation, and 80 feet higher another old opening probably was at the Upper Freeport coal. Section 61, (pl. IX), indicates the stratigraphic intervals northward of this locality.

Beaver Falls Sub-district.

The description of this sub-district, concerning parts of Chippewa, White, and Patterson townships and Beaver Falls and College boroughs, proceeds from the northwest corner southward, thence eastward to Beaver Falls and northward to Wallace Run. For convenience the sub-district is further divided into western, southern, and eastern portions.

Western area. The stratigraphic intervals in the northwestern corner are shown by section 61 (pl. IX). Northward a blossom of the Upper Freeport coal occurs 40 feet below the road corner, or 1110 feet above sea level. The Lower Freeport is 35 feet below it. The upper bed at the nearby banks of Messrs. Hall and Williams, Nos. 277 and 276, is at elevation 1115 feet. The thicknesses are 62 and 52 inches, respectively (Fig. 6, 10, 9). Southward, at No. 254, the elevation has increased to 1165 feet and the thickness is 49 inches (Fig. 6, 5). Eastward, at No. 253, the thickness is 38 inches (Fig. 6, 4) and the elevation 1155 feet. The roads in this vicinity expose the limestone of the East Palestine horizon about 40 feet higher than the Upper Freeport, and still higher 40 feet, the New Gallee clay, which shows its typical flinty fracture and ocherous brown color. Near the western edge of Chippewa township, at No. 255, the Upper Freeport clay blossom is 80 feet below the road corner, or at elevation 1160 feet. The Lower Freeport coal is 35 feet below the clay blossom and the East Palestine, 45 feet above it, or 35 feet below the road corner, where the New Galilee clay is exposed.

Southern area. Along the southern limit of the quadrangle the deep ravines expose the Kittanning coals and the Conemaugh strata cap the hills. The Lower Kittanning in North Branch of Brady Run is at elevation 1005 feet at No. 222 and 1000 feet at No. 223. Eastward the "Three-foot" or Lower Kittanning coal was once opened at No. 224, 990 feet above sea level. Southward, the Middle or Upper Kittanning occurs 50 feet higher, at No. 225 and the Upper Freeport clay blossom is exposed at No. 226, at altitude 1150 feet. This coal is at the same elevation eastward, at No. 228. At No. 227, two small coal blossoms occur 30 and 40 feet lower and are near the Lower Freeport horizon. To the southward, beyond the quadrangle limit, the Lower Kittanning, at No. 229, is at elevation of 975 feet and is 18 inches thick (Fig. 7, 53). To the northward along the Darlington road at Mr. Gilliland's, No. 252, the Upper Freeport is at altitude 1160 feet. Its maximum thickness is reported to be 48 inches (Fig. 6, 3), but this is said to diminish greatly where the sandstone roof cuts out the bed. The coal is 10 feet higher at an old bank north of the road, No. 251, and at the corner between the two, and 35 feet higher occur the coal and limestone of the East Palestine horizon. This limestone is at the same elevation at the road forks to the eastward, No. 250, where it is about 35 feet lower than the New Galilee clay. One mile southward, at No. 230, the Upper Freeport blossom is 55 feet below the hilltop (1145 feet above sea level). The same coal is 5 feet lower to the eastward, at No. 231, where it is only 18 inches thick (Fig. 6, 2). Northward ½ mile, at No. 241, however, this bed in Mr. Twaddle's bank is reported to be of minable thickness and is at elevation 1130 feet. Near the map

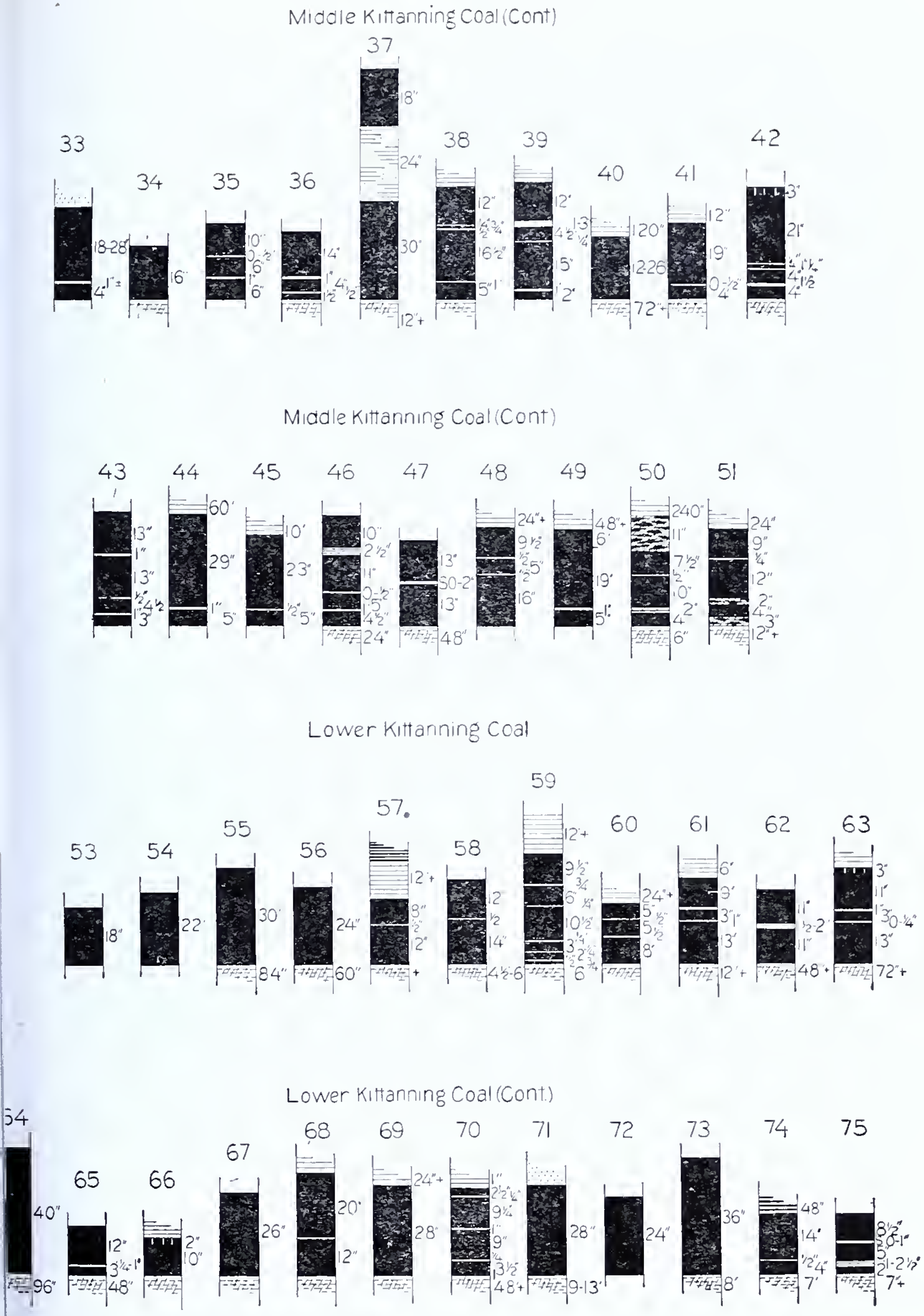

FIGURE 7. Coal sections in south central district.

limit, at No. 232, the Lower Kittanning blossom is exposed near the creek level, or 945 feet above sea. The bed dips southward to elevation 905 feet at Mr. Watson's mine, No. 233, where, 30 inches thick, it overlies 7 feet of fire clay (Fig. 7, 55).

Eastern area. Numerous coal openings and ravine sections occur in the hills in the vicinity of Beaver Falls. Part of the borough lies on a boulder terrace. An excellent section south of the quadrangle below Patterson Heights is shown as No. 31 on pl. VIII. In it, at Mr. Watson's mine, the Lower Kittanning coal is 22 inches thick (Fig. 7, 54), and is 75 feet above the railroad, or 865 feet above sea level. The bed rises to 895 feet at No. 234, where it is 24 inches thick (Fig. 7, 56) and has 5 feet or more of clay beneath. Along the road rising from the Pittsburgh and Fort Wayne depot, at No. 235, the Lower Kittanning is 20½ inches thick at the bank of Winterberger and Bush, (Fig. 7, 57), and is 920 feet above sea-level. A slight westerly dip (5 feet) occurs to the Clayton mine nearby, No. 236, where the average thickness is 30 inches (Fig. 7, 58). There it overlies 4-6 feet of fire clay. Westword the Lower Freeport blossom is exposed beneath the Butler sandstone 10 feet above the road corner, or at altitude 1060 feet. At Mr. Davidson's mine, No. 237, the Lower Kittanning coal is 34 inches thick (Fig. 7, 59), and the underlying clay contains "iron balls." The elevation is 915 feet. The Middle Kittanning occurs 42 feet higher and is 15 inches thick (Fig. 6, 23). At Bissell's bank to the northward, No. 238, the elevations of the Lower and Middle Kittanning coal beds are 950 and 980, respectively. The same elevations obtain at Mr. Beck's, No. 240, where the lower bed is 19 inches thick (Fig. 7, 60). To the southward the Butler sandstone was formerly quarried, as it is also now to the northward at John Boyer's, No. 242. There the elevation of the top is 1245 feet. The face shows 22 feet of thick bedded stone suitable for bridges, curbs and buildings. Section 32 (pl. VIII) was measured in the road up the ravine from railroad level opposite the Anderton brewery. The Pottsville sandstone rises rapidly to the northward. It is overlain by shales containing the horizon of the Brookville coal, along the railroad to the south and again northward at the Wilcox Brick Yards, No. 239. The shale is gray and sandy, suitable for good common bhick. Nearby, at No. 243, the Lower Kittanning bed is worked by Mr. Clayton and is 26 inches thick (Fig. 7, 61). It is 945 feet above sea level. The Middle Kittanning is open 45 feet higher and is 16 inches thick (Fig. 6, 24). Eighty-five feet above it at the road bend the Lower Freeport blossom occurs beneath the Butler sandstone.

College Hill borough is on an upper terrace of alluvial clay and gravel which caps the Homewood sandstone. The sandstone is exposed in the railroad cut west of the race track and also along the river bluffs. Near Morado old quarries, No. 281, show two benches, each 25 or 30 feet thick, separated by an interval of the same size. The beds quarried are coarse, white conglomeratic sandstones, and are regarded as the Homewood and Upper Connoquenessing beds.

In Harbison Hollow west of College Hill the Lower Kittanning coal is worked at Boyd's bank, No. 249, where it is 30 inches thick (Fig. 6, 63), and 995 feet above sea level. Upstream ½ mile, the elevation is the same, but down stream the bed rises gently to 1000 feet at No. 248 and at No. 247 on the Patterson farm. Above the latter bank, the Middle Kittanning was once opened. It is reported to be 18 - 25 inches thick and to overlie fire clay 8 feet thick. In the south ravine at No. 244 the Middle Kittanning coal is 18 inches thick at Mr. Wheeler's (Fig. 6, 25). The elevation is 1015 feet. A slight anticlinal axis near Mr. Patterson's is therefore indicated, and the coal beds dip southeastward to Wheeler's and Clayton's openings and westward to Boyd's mine. At the latter place the bed is said to dip southwestward about 15 feet in 1500 yards. Below Mr. Patterson's and also to the northward at No. 246, the Brookville or "Twin vein" is near creek level, or about 890 feet above the sea. It consists of a top and a bottom bench, 5 and 13 inches thick respectively, and separated by 27 inches of shale (Fig. 8, 79).

Several openings have been made on the Lower Kittanning coal between Harbison Hollow and Wallace Run at elevation about 1000 feet. Section 33 (pl. VIII) occurs here. In the Harbison bank, No. 245, the bed is reported to be from 12 - 25 inches thick (Fig. 7, 62), and to be "rolly" with the thick coal in the "basins." A band ½ - 2 inches thick is said to occur near the middle, and sulphur streaks and balls are present near the floor. The fire clay is sandy to a depth of 4 feet. The Middle Kittanning was found 22 feet higher in the air shaft and is 14 - 16 inches thick (Fig. 6, 26). Northward above the tube works, the Lower Kittanning coal at No. 280 is only 15 inches thick (Fig. 7, 65), and overlies 4 feet or more of soft gray fire clay. At Morado, in section 34 (pl. VIII) the Mercer (?) coal is 0-6 inches thick. Upstream the Brookville at No. 286 is reported separated into a top and bottom bench about 15 and 18 inches thick, respectively (Fig. 8, 80), by 3 - 4 feet of shale. A thin sandy limestone 20 feet higher may be either the Vanport or that shown near the base of section 31 (pl. VIII), and which is possibly the "Putnam Hill" horizon.

In the upland south of Wallace Run the Upper Freeport or "Four-foot" coal was once opened on Mr. Finney's farm, No. 279, where its elevation is 1170 feet. Westward at No. 278 the horizon appears to be 10 feet lower and the coal is missing, the sandstone roof resting on the fire clay.

Big Beaver (Beaver County) Sub-district.

Southern area. This division is the area between the Chippewa Township line and the Pittsburgh, Fort Wayne & Chicago Railroad and Clarks Run. The exposed rocks are those between the Quakertown horizon and slightly above the New Galilee clay. Data are found at numerous old coal banks and in ravine sections. The description proceeds from the southwest corner near Darlington eastward along the hills and Wallace Run to Morado, thence northward to Homewood and westward along the railroad.

Near Darlington, the Lower Kittanning horizon is concealed by glacial deposits, except at the McMahon bank, No. 293, where it is 26 inches thick and is very pure (Fig. 7, 67). Its elevation is 940 feet, and 25 feet above it the Middle Kittanning is 16 inches thick (Fig. 7, 34). To the southeastward, the Lower Freeport outcrops in the road 1070 feet above sea level and was once opened at the McCarrier bank. Northeastward, at No. 292, it blossoms in the road about 10 feet higher and 35 feet below the Upper Freeport blossom. Sixty feet higher than the latter and 35 feet below the road corner an outcropping limestone represents the East Palestine horizon. The elevation of the Upper Freeport coal is 20 feet higher, or 1135 feet at Mr. Secrest's, No. 299, where it is reported as being thin. The usual limestone underlies it and the overlying sandstone is shaly. Above it, 80 feet, the New Galilee clay and coal outcrop in the road. Eastward, on the J. M. Littell farm, No. 291, the horizon of the Upper Freeport is 25 feet below the road, or 1150 feet above sea level. It rises 10 feet from here to the road crossing to the eastward where it makes a conspicuous blossom 5 feet below the road corner and is reported as being 3 feet thick, but sulphury, in a water well. From this corner the beds dip westward and northward. The East Palestine coal outcrops in the road to the westward and 30 feet higher. Northeastward, at No. 289, the Upper Freeport coal is 40 feet below the hilltop or 1180 feet above sea level. It is 10 feet higher at the next road corner, No. 288. There the Lower Freeport coal occurs 40 feet below it and the East Palestine coal and limestone 35 feet above it. The stratigraphic intervals are shown by sections 34 and 35 (pl. VIII) measured near Morado.

Along Wallace Run, the Middle Kittanning coal was once opened below the Creese farm, No. 290, where it is 15 feet below the road and 1060 feet above sea level. It is said to be 22 - 32 inches thick (Fig. 7, 33). The dip is northwestward. Down stream its elevation is 75 feet above the road at Mrs. Mane's bank, No. 287, or at elevation 1055 feet. It is 13-18 inches thick (Fig. 6, 29). Twenty-five feet below it the Lower Kittanning bed is 12 inches thick, with 2 inches of cannel at the top (Fig. 7, 66). Eastward on the Bruce farm (section 34, pl. VIII) the Middle Kittanning seam is 85 feet above the road or 1045 feet above sea level. The part exposed shows 12 inches of coal beneath a sandstone 10 feet thick. The total thickness of the coal is said to be 18 inches. This coal is 30 feet from both the Upper and

Lower Kittanning beds at this point, the Upper being 12 inches thick (Fig. 8, 78). The Middle Kittanning is 15 inches thick (Fig. 6, 27), and is at elevation 1050 feet at the Aley bank where section 35 is exposed. Old banks show that the Upper Freeport and Lower Kittanning are separated from the Middle Kittanning by intervals of 130 and 35 feet, respectively. The thickness of the Upper Freeport is said to range between 6 and 56 inches because of the irregular position of the roof sandstone. Eastward, at Nos. 282 and 283, the Lower Kittanning coal is at elevation of 1010 feet at the old banks of Mr. Robinson and Mr. Wallace. It is reported to be free from impurities and 18 inches thick. Forty feet higher, at No. 282, the Middle Kittanning was formerly worked by Mr. Robinson (Fig. 6, 28).

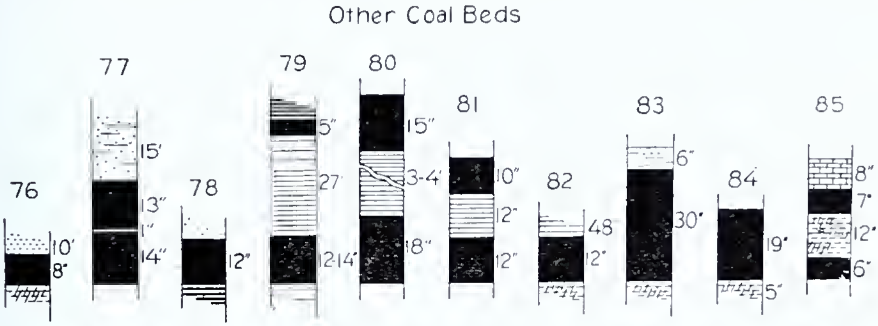

FIGURE 8. Coal sections in south central district.

Other coal openings than those just mentioned occur between Morado and Homewood. On the Robinson place, the Middle Kittanning is 24½ inches thick (Fig. 6, 31), and is at elevation 1050 feet. The relations are shown by section 36.

Eastward on the Grim farm, No. 284, the Brookville or "twin vein" is at elevation 930 feet and is 34 inches thick, but it has a thick parting (Fig. 8, 81). Section 36 (pl. VIII) is exposed in this vicinity. At J. J. Bolton's bank, No. 285, the Middle Kittanning coal is 18½-27½ inches thick (Fig. 6, 32). The elevation of the bed is 1075 feet. Below the bank, 30 feet, occurs the Lower Kittanning, and 90 feet above the Middle Kittanning, an old prospect indicates the horizon of the Lower Freeport.

At Homewood section 37 was measured (pl. VIII). Southward at No. 305 the Lower Freeport limestone is at elevation of 1140 feet. The Upper Kittanning, 55 feet lower, is 8 inches thick (Fig. 8, 76), and is 15 feet above an old bank on the Middle Kittanning and 50 feet above the Lower Kittanning. The latter bed is reported to be 2 feet thick,[43] (Fig. 7, 72). A coal blossom in the road at elevation 980 feet, lies at or near the Clarion horizon. It is 55 feet below the Lower Kittanning and 15 feet above the shaly sandstone which there is seen 15 feet thick along the railroad and above the sandstone quarry, No. 306. This coal is probably the same as that occurring in the road ½ mile north, under a thin-bedded blue-gray sandstone, elsewhere seen to underlie the Vanport limestone. This interpretation differs from that of I. C. White, who assumes that the massive quarry sandstone extends above the Vanport horrizon.[44] The Homewood sandstone is quarried in a 50-foot face, showing massive to irregularly bedded structure. It is gray to white in color and of medium grain. The total vertical distance from top to bottom of the sandstone is 130 feet, but the southeastern dip of the beds exaggerates the actual thickness by 20 or 30 feet. The unusual thickness is thought to be due to the union of the Homewood and Upper Connoquenssing sandstone, although White regarded the entire mass as "Homewood".

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[43] Pennsylvania Second Geol. Survey, Report Q, p. 225.

West of Homewood, at No. 304, old openings on the Middle and Lower Kittanning coal beds are at elevations 1060 and 1030 feet, respectively. Westward at No. 303 the Lower Freeport limestone outcrops as a bed of deep yellow blocks 1110 feet above sea level, or 30 feet lower than at No. 305 south of Homewood. The Middle Kittanning was once opened at No. 303 and in this general vicinity it is reported to be 21 inches thick[45] (Fig. 7, 36). Westward at No. 302 it is 23½ inches thick (Fig. 7, 35) and is 1030 feet above sea level. The Upper Freeport blossom occurs at Nos. 301 and 300, at elevations 1145 and 1135 feet, respectively, and its underlying limestone is at the top of the "Summit Cut", 1125 feet above sea level. There the Lower Freeport coal is 57 feet lower, as shown by section 64 (pl. IX), and is 18 inches thick (Fig. 6, 17). Farther westward, in section 63 (pl. IX), this coal makes a road blossom at elevation 1080 feet and the Upper Freeport is 50 feet above it. The Middle Kittanning blossom is 5 feet below the railroad or at elevation 1005 feet, and to the southward the Lower Kittanning is 30 feet lower. East of the railroad arch, at Harlow (name not on map), the Middle Kittanning is 10 feet above the track or 995 feet above sea level. Westward, the Lower Kittanning is 55 feet lower at the old Strowbridge bank, No. 298, where it is said to be 28 inches thick (Fig. 7, 71) and to overlie 9-13 feet of fire clay.

Northern area. The area between the Pittsburgh, Fort Wayne & Chicago Railroad and the Lawrence County line offers many exposures of the strata between the Quakertown coal and slightly above the New Galilee clay. The description proceeds from the "Summit Cut" westward and northward to Jordan Run, thence eastward and southward to Homewood and northward to Hoytdale.

The exposure at "Summit Cut" has already been mentioned. At its top the Upper Freeport limestone is at elevation 1125 feet. Half a mile north, the limestone is 15 feet higher. Westward, near 298, a terrace of sand and gravel, 40 to 60 feet thick, was formerly excavated for ballast. Near New Galilee there are several coal and clay openings. Section 65 (pl. IX) was obtained from that vicinity. At the plant of the Beaver Clay Manufacturing Company, No. 319, the Lower Kittanning bed, 19 inches thick, is reached by shallow shaft and slope. The Middle Kittanning coal blossom is about 25 feet higher. At the slope the coal is 7 feet below the railroad, its altitude being 960 feet. The clay consists of two parts: a soft 4-foot bed overlying a much harder and more siliceous portion about 6 feet thick. Northward at the shaft the elevation of the coal is 980 feet. There the fire clay is 9 feet thick or more. The slope of the bed continues upward to 1,005 feet at the abandoned plant to the north, No. 320, where the coal is 18 inches thick (Fig. 7, 74), and the clay 7 feet thick or more. Above the shaft the Lower Freeport is at elevation 1075 feet. It is 28 inches thick. Clay 3 feet thick and limestone are exposed beneath the coal. Another clay 6 feet thick is said to be beneath the limestone. The Mahoning sandstone 35 feet thick is exposed at an old quarry here, its top being 75 feet higher than Lower Freeport coal, and 20 feet below the limestone of the East Palestine horizon. Eastward at Mr. Greeg's, No. 318, the Upper Freeport coal is 36 inches thick at the pit mouth (Fig. 6, 11), but under the hill it is reported to be from 6 feet to 1 inch or so thick. The Coal is beneath the Mahoning sandstone at elevation 1130 feet, and boulders of the East Palestine limestone occur 40 feet higher. The coal has the same elevation at Squire Anderson's, No. 317, where it is 75 feet below the New Galilee clay. This is the type locality of the latter bed. It is 12 feet thick or more, shows flinty structure ,and is reported to be of good quality, although its yellowish-brown color suggests the presence of some iron. The clay occupies several hilltops as indicated by the map. Northwestward, along the road, at No. 322, the Lower Freeport was once opened at elevation 1080 feet. In the hill west of New Galilee, a blossom of the Lower Kittanning was observed at altitude 950 feet. Old openings, 70 and 145 feet higher, respectively (No. 321) were probably on the Lower and Upper Freeport coals.

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[44] Pennsylvania Second Geol. Survey, Rept. Q, p. 225.
[45] Second Geol. Survey of Penn., report Q, p. 225.

On the Patterson farm along Jordan Run, where section 66 occurs, the Lower Freeport coal is 1085 feet above sea level, and is 30½ inches thick (Fig. 6, 19). The Upper Freeport is 40 feet higher, and the Middle Kittanning 82 feet lower, or 1005 feet above sea level, at a mine in which it is 12 - 26 inches thick (Fig. 7, 40). It overlies a fire clay 6 feet thick. The Lower Kittanning is close to water level and is reported to be 20 inches thick. The Lower Freeport has the same elevation, 1085 feet, near the schoolhouse, No. 323, where it is mined for local trade: Northward, at Nos. 324 and 325, the Middle

Kittanning coal is at elevations 1010 and 1025 feet, respectively, being higher and higher along the axis of the syncline. Nearby, at No. 326, is a bed of small gravel 25 feet thick.

Eastward in the hill area, the Upper Freeport, at the entry of an old mine, No. 327, is 89 inches thick and is 1145 feet above sea level (Fig. 6, 12). Nearby at No. 328, the East Palestine limestone and coal blossom is 150 feet higher, or 15 feet below the hilltop. The same coal makes a wide blossom to the southward, where it is 45 feet below the road corner, or 1190 feet above sea level. The New Galilee clay and coal blooms occur in the hill areas, and, at No. 316, appear at the road forks at elevation 1225 feet. In the road half a mile toward Homewood the East Palestine coal is at elevation 1190 feet. Down the run at Nos. 310 and 309, the Middle Kittanning was formerly opened at elevation 1055 and 1070 feet, respectively. These data indicate that the anticlinal axis rises to the southeastward.

North of Homewood, above the terrace, the Lower Kittanning was formerly opened at No. 307, where the elevation is 1025 feet. Above it 105 feet, the Lower Freeport limestone outcrops on the hill top. In the public road to the eastward, a thin coal bloom 35 feet higher than the railroad is overlain by thin, laminated blue-gray sandstone which elsewhere in the area is beneath the horizon of the Vanport limestone. The coal is regarded as being the Clarion; it lies 20 feet lower at No. 308.

At Stockman Run, section 40 (pl. VIII) is exposed. The Lower Kittanning coal at No. 312 makes a thick blossom and is probably about 3 feet thick (Fig. 7, 73). The underlying fire clay is reported to be 8 feet thick and to make excellent saggers. The Vanport limestone is possibly present, 1 foot thick, 18 feet below this coal.[46] Thirty feet above the Lower Kittanning bed, or at elevation 1050 feet, the Middle Kittanning is opened and is 36 inches thick (Fig. 7, 38). At Mr. Blair's, No. 311 the elevation is the same, but a sandstone parting separates the coal into upper and lower benches, 18 and 30 inches thick (Fig. 7, 37). Northward several old openings on this bed indicate a northwest dip. At No. 313, the elevation is 1030 feet and the thickness 37 inches (Fig. 7, 39). The Lower Freeport limestone there is 70 feet above the Middle Kittanning coal, and at No. 314, 10 feet higher, where it underlies a coal 10 inches thick (Fig. 6, 20). In the hilltop, 110 feet above this coal, or 1220 feet above sea level, the New Galilee clay and coal occur. Nearby at No. 315, the East palestine blossom is at altitude 1190 feet. The Upper Freeport limestone is in the run near the McKim house to the northward, at elevation 1155 feet.

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[46] Pennsylvania Second Geol. Survey, Rept. V, p. 193.

At Hoytdale, an old mine, No. 330, on the Middle Kittanning coal, is 1010 feet above sea level. The Upper Freeport blossom is 140 feet higher in the road. Northward, at No. 331, the Middle Kittanning is at elevation 1030 feet at John Pratt's bank, and is 23½ inches thick (Fig. 7, 41).

The river cliffs from Homewood to Hoytdale expose the Pottsville beds, as shown by sections 37, 38, 39, 40 and 41, pl. VIII. These and the sections east of the river indicate considerable irregularity in the stratigraphy, making correlation doubtful. At No. 338, the old Beattie bank shows 6 - 30 inches of good coal, at elevation 840 feet (Fig. 8, 83). It is beneath the Homewood sandstone, which descends northward and causes the coal to pinch out. This coal is thought to be the Homewood coal which is absent in the Homewood section; and not the coal in that section at the base of the sandstone, 820 feet above sea level, with which it was correlated by I. C. White.[47] At the quarry of the Clydesdale Stone Company, the Homewood sandstone shows a 40-foot face, beneath which coal streaks and shales with iron carbonate nodules are at the Homewood or Mercer horizon. The top of the quarry is at elevation 870 feet and, probably, about 30 feet of the bed has been eroded. A coal blossom 70 feet lower and near railroad level, probably is the Quakertown seam. The ravines at West Ellwood Junction and Hoytdale show the top of the Homewood sandstone at elevation 895 and 880 feet, respectively. Streaks of fire clay and coal occurring below are at the Homewood and Mercer horizons.

Lawrence County Sub-district.

That portion of the district in Lawrence County is constituted by almost all of Big Beaver and the extreme southeast corner of North Beaver townships. The range of outcropping rocks is from below the Quakertown coal to above the New Galilee clay. The Mercer group is present. The description begins at Possum Hollow and proceeds northward to Wampum and thence westward and northward to the limits of the sub-district.

Possum Hollow to Wampum Run. The river terrace from Possum Hollow to Wampum Run is covered by drift, but the bluffs expose Pottsville sandstones. The lower part of section 41 (pl. VIII) is taken from White's report.[48] Northward at an old quarry, No. 332, the massive Homewood sandstone is 10 feet thick and somewhat conglomeratic. Its top is at elevation 880 feet and shows glacial scratches or striae indicating a S. 35°E. movement of the ice at this place. Northward ⅝ mile at the No. 2 quarry of the Clydesdale Stone Company, No. 340, the sandstone is 30 feet thick. Its top is 890 feet above sea level, but has been considerably eroded, for pot holes are present and indicate that the river formerly flowed at this level. Northward the Beaver Valley Sandstone Company quarried the Upper Connoquenessing bed at No. 343. The top of this bed is at elevation 830 feet and its thickness is 40 feet. The lower 10 feet is the most massive and regular portion, and at its base occasional "pots" of thin coal indicate the Quakertown horizon, as shown by section 42 (pl. VIII).

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[47] Pennsylvania Second Geol. Survey, Rept. Q, p. 225.
[48] Pennsylvania Second Geol. Survey, Rept. QQ, p. 239.

Along the road from Possum Hollow to Wampum Run, several coals and the Vanport limestone are exposed. Section 41 (pl. VIII), at Possum Hollow, indicates the stratigraphic intervals. The Middle Kittanning coal was formerly washed and shipped from this locality on a large scale, but only local banks are now worked. At No. 334 the coal is 35 inches thick (Fig. 7, 43) and is at elevation 1035 feet. A similar section occurs at No. 335 (Fig. 7, 42). Eastward along the road, at No. 333, an 18-inch bed of very calcareous sandstone at elevation 970 feet probably represents the Vanport limestone, or possibly the Clarion horizon as suggested by Chance.[49] Northward at No. 339, the Middle Kittanning elevation is 1010 feet and the thickness is 35 inches (Fig. 7, 44). At No. 341, the bed is at elevation 1050 feet and is 28 inches thick (Fig. 7, c. s. 45). A quarter of a mile north the Vanport limestone is 10 feet thick or more, and its top is at 955 feet. Southward of this place the limestone thins and is not exposed. Northward, at a quarry of the Crescent Portland Cement Company, No. 342, the elevation of the limestone is the same and its thickness is 20 feet. The Lower Kittanning coal is 30 feet higher and is 10 inches thick. Its fire clay is 7 feet thick. The Middle Kittanning which is 35 feet still higher, or 1015 feet above sea level, is 31 inches thick (Fig. 7, 49) and overlies a fire clay 5 feet thick. At the quarry at Wampum, No. 344, the same coal is 67 feet above the top of the limestone. The latter consists of two parts; the top is gray and the bottom blue. The gray stone may be divided into three layers on the basis of difference in composition and appearance.

Section of Vanport limestone at Wampum.

	Layer	Thickness	
		Feet	Inches
Top or gray	"Gray"	7	6
	"Bull"	1	10
	"Bessemer"	4	
Bottom or blue	"Blue"	8	
		21	4

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[49] Pennsylvania Second Geol. Survey, Rept. V, p. 196.

The blue-gray clay shale occurring above the limestone is mixed with the latter for making cement. Just to the west a later plant was erected by the Wampum Lime Company. Since then it has been acquired by the Crescent Portland Cement Company.

In the upland area lying between Possum Hollow and Wampum Run, the Middle Kittanning and Upper Freeport coals have been worked out. At No. 338, the lower bed or "Three-foot" is at elevation 1030 feet, and the Upper Freeport or "Six-foot" is 125 feet higher. It dips 15 feet in passing to Nos. 337 and 336, where exposures show a 62-inch face (Fig. 6, 13).

Wampum-Coverdale area. Sections 43 and 44 (pl. VIII) occur in the vicinity of Wampum. The Upper Mercer coal outcrops just above railroad level at the depot, and the Lower Mercer, about 15 feet below it. Thirty feet of the Homewood sandstone in section 43 (pl. VIII) is exposed in a quarry. The top of the sandstone is 885 feet above sea level. Nearby, at No. 345, the Upper Mercer limestone and coal are along the railroad siding at about 810 feet altitude. There the following section is exposed.

Section at Wampum, No. 345.

	Feet	Inches
Sandstone (Homewood)	2	
Sandy shale, brown	7	
Shale, dark brown	4	
Limestone		4
Shale, dark	3	
Limestone, dark	1	6
Coal, bony (Upper Mercer)		8
Shale, dark	4	
Concealed	5	
Shale, dark brown	5	
Coal, (Lower Mercer)		8
Shale, ferruginous	5	
Concealed	10	
Sandstone, white thin-bedded to massive.	10	
Total	58	2

Up Wampum Run the Homewood coal blossom is at elevation 860 feet and is beneath massive sandstone 5 feet thick. Nearby, at No. 346, the Middle Kittanning coal is 140 feet higher and is worked for local consumption. In section 44 (pl. VIII) the same coal has been opened about 25 feet higher. Below it, the Wampum Crushed Limestone Company worked about 10 feet of the Vanport bed, from the top of the "bull" layer downward, the upper portion having been removed for flux by former operators.

In the hilltop south-southeast of Wampum on the Cunningham farm, the Upper Freeport coal occurs in a small area, and is worked for local use by Beyers Bros. The bed is at altitude 1140 feet, and furnishes clean black coal 54 inches thick, except for a thin shale band near the base (Fig. 6, 14). The roof is sandstone. An old prospect drift to the west, No. 347, and about 75 feet lower, shows the Lower Freeport bed is 25 inches thick (Fig. 6, 22) underlain by fire clay 2 feet thick and a limestone bed. The coal seems to be bony but it is not freshly exposed. It appears to have a thin shale roof above which occurs 10 feet of irregularly and thick-bedded sandstone—the Butler.

At Coverdale are two commercial mines and several smaller openings. The mouth of the main mine of the Crescent Portland Cement Co., formerly operated by the Beaver Coal & Coke Company, No. 351, is on the Middle Kittanning coal, at elevation 1040 feet. The coal is 30 - 44 inches thick averaging 34 inches, with the partings shown on coal section 46, Fig. 7. It is bright and of moderate hardness. The coal has a roof of shale 6 - 9 feet thick, well suited for mining purposes. The floor is fireclay 2 - 3 feet thick underlain by hard blue rock. The clay has a tendency to "squeeze." The workings extend southward more than a mile from the pit mouth to the drainage shaft near the county line, No. 329, and from this line a quarter to half a mile in an east-west direction, to the former workings, which were driven from Possum Hollow. According to the mine map, the coal, in general, dips southward, but the dip is mildly irregular. Westward from the road corner, midway along the main workings, the coal is cut by an old north-south creek valley now filled with glacial drift. It is present, however, a short distance to the west. Pockets of sand 30 or more feet thick are dug for local use from the valley south of Coverdale. The Beaver Coal and Coke Company acquired the mine of the Wampum Run Coal Company. The tipple and old entry are at No. 349, but haulage was later from a newer entry to the south, No. 352. The coal is at elevation 1030 at both places, and, judging from the accumulated water, is 15 feet lower at the nearby shaft, No. 353. The bed is 30-36 inches thick and averaging 34 inches, showing similar section to that at the old mine of the Beaver Coal and Coke Company (Fig. 7, 46). The roof is slate; but is, if anything, too strong for easy mining. The floor is soft fire clay 1½-2 feet thick, over a harder portion 2 - 4 feet thick.

Other data in this vicinity are furnished in the hill to the eastward and northward. At No. 350, the Middle Kittanning blossom is at elevation 1040 feet. Twenty-five feet below, the Lower Kittanning or "18-inch" bed occurs with a heavy fire clay. Northward at No. 348, the Middle Kittanning bed has the same altitude, 1040 feet, but shows a bony coal and only 21 inches workable (Fig. 7, 50).

Westward, where section 45 (pl. VIII) occurs, the Upper Kittanning coal is exposed in an old railroad cut. It is overlain by shaly sandstone 25 feet thick. The coal is 27 inches thick and has a 1-inch band in the middle (Fig. 8, 77). Its elevation is 1055 feet, only 15 feet higher than a nearby opening on the Middle Kittanning bed. The irregular extent of the Upper bed is indicated by the report of the shaft, No. 353, where 30 feet of shale overlies the Middle Kittanning coal, and an old shaft in the hill east of Coverdale, where 90 feet of shale and sandstone overlies the same bed. It is suggested that the Lower Kittanning clay of this vicinity is worth prospecting and testing for refractory purposes.

Area north and west of Coverdale. One mile northwest of Coverdale, the elevation of the Middle Kittanning coal is 1050 feet at an old bank, and 1060 feet at No. 359, where it was worked by a 20-foot slope at the Montgomery bank. There the quality of the bed is good. The good coal is 26 inches thick (Fig. 7, 51). Farther north, at No. 360, old banks at elevations 1085 and 1150 feet probably indicate the horizons of the Middle Kittanning and Lower Freeport, respectively, although the evidence is not conclusive. Northeastward, at No. 361, one of the Mercer coals is exposed in the creek, 25 feet below the road corner, or 920 feet above sea level; another coal (Fig. 8, 82), probably the Brookville, is 50 feet above the first coal at the roadside. The exposed section is as follows:

Section 1 mile west of Irish Ripple at No. 361.

	Feet
Shale	4
Coal (Brookville?)	1½
Fire clay	
Concealed	25
Shale, brown	10
Sandstone	1
Shale	3
Limestone (Mercer)	1½
Coal	1
Fire clay	1

Near the mouth of Jenkins Run, No. 362, the top of a 35-foot cliff of sandstone is at altitude 815 feet. It is a massive bed of very small grain and brown color. Five feet above its base occurs a 16-inch band of flinty pebbles and iron carbonate nodules, overlain by coal 4 inches thick. This is thought to be the Quakertown horizon, which commonly underlies the Upper Connoquenessing sandstone. A short distance to the east, a roadcut shows fine sand or silt 20 feet thick capped by reddish brown gravel 10 feet thick.

West of Coverdale, and along the valley of Little Beaver Creek, occur several old coal openings. One, at No. 354, near the school, and 1090 feet above sea level, probably is at or near the Lower Freeport horizon. Westward, at No. 355, Mr. Wells has a bank on the Middle Kittanning 70 feet above the road crosssing, or at altitude 1039 feet. The bed shows coal 26 inches thick with a 2-inch sulphur band in the middle (Fig. 7, 47) and is reported to overlie a fire clay 6 feet thick. Northwestward one mile, at Mr. Buchanan's bank, No. 357, the same bed is 20 feet higher and shows good coal 31 inches thick (Fig. 7, 48). North of Mr. Wells,' on the Cosgrove farm, an old bank, No. 356, at elevation 1125 feet, is reported to show a coal 4 feet thick under a sandy shale roof (Fig. 6, 21). This is one of the Freeport coals, probably the Lower. Northward, at No. 358, and at elevation 1195 feet, the Upper Freeport was formerly opened along the west side of the road. It is reported to be a good coal 2 - 4 feet thick with sandstone roof and fire clay floor (Fig. 6, 15).

ECONOMIC SUMMARY

Coal.

The rocks of this district expose ten or more coal horizons and several of them are of economic importance. In the past the Middle Kittanning coal has been extensively mined from Wampum to Stockman Run. Other beds formerly worked are the Upper and Lower Freeport, and the Lower Kittanning. At present the Upper Freeport and Lower Kittanning offer inducements for further testing and development. The Lower Kittanning is especially attractive because of its underlying fire clay. The conditions of the important beds are summarized here, and methods of mining are given on a later page.

Middle Kittanning coal. The outcrop of the Middle Kittanning coal is shown on the map (pl. IV). Its elevation is shown by the structure contours. It probably underlies 45 - 50 square miles though workable under only part of the area. As shown by the accompanying coal sections, Figs. 6 and 7, the coal where exposed is 12 - 48 inches thick, the average being about 24 inches. In the vicinity of Wampum and southward many sections show the bed to be as much as 34 inches thick; from the mouth of Wallace Run to Beaver Falls, however, the seam is too thin to be profitably mined. Similar condition probably exists in the western and southwestern parts of the district, but adequate prospecting has not been done.

The impurities visible in most of the sections consist of streaks or bands of shale, fire clay, and, less commonly, of iron pyrite. In 60 per cent of the sections a clay band occurs 4 - 6 inches above the floor, and in about one-half of these a second band is 13 - 22 inches above the floor. In about one section in five a thin "sulphur" streak is in the middle of the coal. In spite of the impurities the Middle Kittanning is the best coal in the district. Its quality is shown by analyses on a later page.

The roof of the bed is nearly always brown shale, although in Wallace Run sections sandstone occurs in this relation. The fire clay floor is usually of undetermined thickness.

Lower Kittanning coal. The Lower Kittanning coal in this district is valuable chiefly for its underclay, but it is workable on its own account under much of the area. The accompanying sections (Fig. 7) indicate the measured or reported thickness at the numbered localities noted on the map. Observed thicknesses are 12 - 34 inches. South of Cannelton, the bed is reported to be 40 inches thick. In one-half the measured sections the thickness exceeds 2 feet. This may be regarded as workable.

The structure of the coal and distribution of impurities vary greatly. Many of the sections show black lustrous faces, free from clay or sulphur. Others, however, contain a band of pyrite and shale ½-1 inch thick at the middle of the bed. In one instance the band is reported to be 2 inches thick. In a few exposures the top coal is blocky, and in two cases a thin layer of cannel coal is at the top of the bed.

At Beaver Falls the top coal is hard, dull, sulphurous, and open burning, but the lower bench is soft, bright, oily, and coking. The coal slacks readily, and the slack makes firm, porous coke of beautiful silvery lustre.[50]

Analyses referring in part to this coal, are given on a later page.

The roof of the bed, wherever observed, is hard shale or "slate." In one instance it is reported to be sandstone. The floor is fire clay, which, locally, is 16 feet thick.

The Lower Kittanning coal is widely distributed in this district. The outcrop line around its borders (see pl. IV) includes areas somewhat greater than those of the Middle Kittanning, being approximately 50 - 53 square miles. It is eroded only along the Beaver and Little Beaver and their larger tributaries. The thickness and quality of the unweathered coal where not exposed is yet to be generally demonstrated by further developments. It is workable at certain places west of Beaver Falls, but it appears to be thin at Morado. Farther north it has been regarded as less promising than the next higher coal, and little is known about it. Along the western edge of the district the bed is workable between New Galilee and Darlington, and is likewise so reported south of Cannelton, and again near the head of

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[50] Pennsylvania Second Geol. Survey, Rept. Q, p. 247.

Brush Run at the southern limit of the district. In general, for itself and associated underclay the Lower Kittanning bed deserves systematic testing wherever it lies within easy reach of transportation.

Upper Freeport coal. The Upper Freeport or "Six-foot" was formerly mined in the vicinity of Wampum until the deposits were exhausted. It is still worked for local use in the upland areas of the district, and underlies approximately 23 square miles. Areas in Chippewa and South Beaver townships seem to be especially attractive and worth prospecting. Development has been handicapped by lack of transportation facilities, but Highway Routes 204 and 354 will ameliorate this condition.

The thickness of the coal ascertained at the points indicated on the map by numbers, and as represented by the sections on Figure 6, is 6 feet or less. Only two sections show the coal to be less than 2 feet thick; but this of course is not necessarily the thinnest development of the bed. Rolls in the roof doubtless reduce the thickness in considerable areas and would necessitate careful drilling in advance of mining. Judging from exposures, the face is locally free from visible impurities, but more commonly bands of pyritiferous shale occur near the floor. One such 1-3 inches thick is frequently to be found 3 - 8 inches above the base, and, less commonly, another about 1 inch thick is about a foot above the floor. Analyses of the bed are presented on a later page.

The roof of the Upper Freeport coal is the Mahoning sandstone; in about one-half of the noted exposures, however, a stratum of brown shale separates the coal and sandstone. The fire clay floor is 1-5 feet thick and is underlain by hard limestone.

Lower Freeport coal. The Lower Freeport coal of the district is not prominently exposed either in mines or outcrops, except in the vicinity of New Galilee. The area underlain by its horizon is slightly larger than that of the Upper Freeport, but on the map this position is shown only where exposures actually occur. The accompanying sections, Figure 6, indicate exposures actually noted at the localities numbered on the map. The coal is 10 - 30 inches thick except in the case of No. 21 (locality No. 356) where it is 48 inches thick; but this may possibly be the Upper Freeport coal. Where mined, near New Galilee, the bed is 28 - 30 inches thick and is held in high esteem, though not so high as the Middle Kittanning.

Clay and Shale.

The clay and shale products of this district are important. These are derived largely from the Lower Kittanning fire clay, but in part also from shale excavated for brick and for Portland cement manufacture. Doubtless the clay industries of this area will expand, for clays and shales are present in large quantities at several available horizons, as shown by accompanying sections and maps. Analyses and notes on manufacturing methods are presented on later pages.

Fire clay.

Lower Kittanning fire clay. The Lower Kittanning fire clay in this district is mined at Darlington by the Darlington Brick & Mining Company, the Alliance Brick Company, and the Darlington Clay Products Co.; and near New Galilee by the Beaver Clay Manufacturing Company. The principal product is face front brick, but others, such as common brick, vitrified pavers and ornamental brick have been made. West of Ellwood Junction, No. 312, the clay has been mined for use as "saggers." Methods of mining and working the clay are described on later pages.

This horizon is directly beneath the Lower Kittanning coal; hence, the line on the map (pl. IV) representing the outcrop of the Lower Kittanning coal may also be construed as representing the outcrop of the fire clay. The area underlain by this horizon also corresponds to that underlain by the coal; viz., 50 - 53 square miles. The condition of the clay in the interior of the area is problematical, but around the outcrop where exposed by weathering and where trenched in the coal banks, the clay has a thickness and appearance which warrant thorough testing.

The accompanying sections (Fig. 7) at over a dozen scattered localities show the clay to be 4 - 13 feet thick. Where best exposed the bed consists of an upper, gray, fine-grained, plastic portion about 4 feet thick, which grades into a lower hard, sandy shale of the gray color, locally known as "silica rock." Portions of each are used.

New Galilee clay. The New Galilee clay horizon is shown on the map well inside the area of the Upper Freeport coal. This occupies only the higher hills of the district. It is very persistent horizontally and appears to be 8 - 15 feet thick. As exposed in a test opening on the W. H. Anderson farm, No. 317, the clay is 12 feet thick and has the typical appearance of flint clay. Little is known of the value of this bed, but Mr. Anderson states that it is as good as the Mount Savage clay. As commonly exposed the color of the clay is orange-brown. The presence of iron is indicated. In some outcrops, however, the clay is cream color, suggesting greater purity.

Other possible fire clays. Each of the numerous coal horizons of this district may be underlain by fire clay, but the beds which have been mentioned are the most attractive. Formerly the Upper Freeport clay was mined for furnace lining at the Summit Cut, where it was 2 to 10 feet thick. The Lower Freeport clay has been tested near the plant of the Beaver Clay Manufacturing Company, No. 319. Mining it there would be expensive, judging from the report that the clay occurs in top and bottom benches respectively 2 and 6 feet thick, but separated by limestone 2 feet thick.

Shale.

Shale beds are important sources of material in this district. The material used by the Darlington Brick and Mining Company is a lumpy brown shale occurring above the Lower Kittanning horizon. It is exposed 45 feet thick and is used by mixing with the fire clay. At Beaver Falls the Wilcox brick yards, No. 239, used a clay shale 7 feet thick which occurs at approximately the Brookville horizon. The same bed is exposed along the Pennsylvania Railroad tracks between Beaver Falls station and the Anderton brewery. As indicated by the stratigraphic sections, the Allegheny and Conemaugh groups contain great thicknesses of shale. The shales of the Allegheny group are more available for working at or near railroad level, and in many places are usable for brick making. A particularly good development occurs above the horizon of the Vanport limestone. In the northern part of the district this shale over the limestone is utilized in the manufacture of Portland cement. At the Crescent Portland Cement Company's plant the shale is in two portions, the top being brown, thinly laminated, 10 feet thick, and the bottom, blue-gray, lumpy, and 6 feet thick.

Alluvial clay.

As indicated by the maps, extensive alluvial deposits occur either on terraces or in the river flood plains. The material along the Beaver terraces resembles that utilized at Ellwood City for making common brick, and south of the quadrangle for terra cotta. By mixing with the Lower Kittanning clay this material is suitable for the manufacture of flower pots. It is a fine-grained sandy silt, buff in color, with occasional small pebbles present.

The flood plain clays although appearing to be sandy and to contain gravel, can probably be utilized for common brick and for better products upon the addition of shale or fire clay.

Limestone.

Limestone occurs at several horizons in this district as shown by the accompanying sections, but only the Vanport limestone is valuable. The East Palestine bed appears thick enough for small development east of Darlington and southeast of New Galilee, but the quality of the bed has not been determined. The Freeport limestones are widespread, but are too thin, and probably are too impure to be utilized. The two Mercer beds are exposed only at Wampum, and are likewise worthless. As exposed by the Crescent Portland Cement Company at Wampum, the Vanport limestone is composed of a gray upper part about 13 feet thick, and a blue lower layer 8 feet thick. The upper part is suitable for, and has been utilized as flux. Both parts are usable for making cement, lime, and ballast. Elsewhere in this district this limestone is only a foot or so thick where exposed, and the absence of exposures implies like conditions over most of this area.

Sandstone.

Sandstone has been produced on a commercial scale from several geologic horizons in this district. The material is suitable for buildings, bridges, and curbs, besides the less important use as rip-rap and rubble. The table on p. 113 indicates the names of the horizons, the thicknesses, and the uses made of stone at the quarries examined.

Homewood sandstone. The Homewood is the most important bed along the Beaver Valley because of its good character, its favorable exposures, and its situation near railroad level. Where exposed its thickness is 20 - 50 feet. Characteristically it is thick and regularly bedded or massive, and fairly free from joints. It has a light-gray or white color, medium or coarse texture, and is composed of sharp silica grains. Locally the color is yellowish or pink, and the upper 15 feet or more is thin-bedded or shaly. The rock is hard and durable. It is exposed in the upper quarry at Wampum and southward from that place for about 2 miles along the Pennsylvania Railroad. The largest exposures occur at West Ellwood Junction, Homewood, and at Morado. Little or no stripping is required.

Upper Connoquenessing sandstone. The Upper Connoquenessing sandstone is exposed just south of Wampum at the quarry of the Beaver Valley Sandstone Company, and at an old quarry at Morado. At the former location the bed is composed of several irregular layers aggregating about 42 feet thick, of which the lower 9 feet is used as dimension stone for bridges and heavy foundations. It is light-gray in color, and coarse-grained to finely conglomeratic in texture. The upper portion, white to deep yellow, is cross-bedded. At Morado the upper 5 feet is thin and irregularly bedded. The lower 30 feet is massive without joints or bedding planes. No stripping is required.

Butler sandstone. The Butler sandstone has been quarried only at Beaver Falls by Mr. John Boyer. It is exposed in a face 22 feet high, and occurs in regular beds 1 - 5 feet thick with smooth bedding planes. Irregular joints cross the beds and are filled with calcite. The rock is of small to medium sized grain, and is so friable as to be easily cut in all directions. It is reported to "case harden" and resist weathering. The stripping may be as much as 5 feet of soil and 20 feet of shale. The locality is about 400 feet above railroad level.

Mahoning sandstone. The Mahoning sandstone was formerly quarried near New Galilee, on the Patterson farm along Jordan Run, opposite No. 323, where it is exposed 60 feet thick in a massive face. Southward it is exposed in a 35-foot face in the hill near the Beaver Clay Manufacturing Company in section 65 (Pl. IX), where it is massive or irregular-bedded and of medium sized grain. It is white, with brown grains of iron oxide.

In this area one of the best opportunities for renewal of quarrying is offered by extending the Patterson quarry farther around the hill, and running a spur from the railroad to Jordan Run. A large quantity of rip rap stone is immediately available from past work.

Sandstone quarries of South Central district.

Map No.	Name.	Character of shipments.	Name of bed.	Exposed thickness Feet.
242	John Boyer	Curbing building, dimension stone.	Butler	22
281	Idle	Dimension stone.	Homewood, Upper Connoquenessing	25 35
306	Clydesdale Stone Co.	Dimension stone, rip rap, rubble.	Homewood	50
339	Clydesdale Stone Co.	Dimension stone, rubble, concrete, engine sand.	Homewood	40
340	Clydesdale Stone Co. No. 2	Dimension stone, rubble.	Homewood	20
343	Beaver Valley Sandstone Co.	Dimension stone, rubble.	Upper Connoquenessing.	42
343	Idle	Dimension stone.	Homewood	35
365	Idle	Dimension stone.	Mahoning	35
323	Patterson	Building stone.	Mahoning	60

Sand and Gravel.

Neither sand nor gravel is shipped from this district, although there is an abundance of both for local use. Formerly gravel was dug extensively from a terrace 1½ miles south of New Galilee along the Fort Wayne tracks. There the bed is 40-60 feet thick and consists of intermingled sand and gravel, with occasional pockets of clean sand. Near the head of Jordan Run, half a mile south of the county line, the public road passes a bed of sand and gravel 25 feet thick. Likewise, 1 mile south of Coverdale a bed of fine sand 30 feet thick is exposed. There is a knob of small gravel at Hoytdale, and many sand and gravel pockets occur west and north of Wampum. Between

Irish Ripple and Moravia a pit along the road shows reddish brown gravel 10 feet thick. Part of Beaver Falls is built on a great bed of large gravel or boulders, with little or no fine clay or sand intermingled.

WESTERN DISTRICT.

GENERAL STATEMENT.

The western district, which is bounded by the west State line and Little Beaver and Honey creeks, (fig. 3), includes a considerable flood plain, but is essentially a dissected upland. Its relief is strong and its slopes steep in the southern portion, but in the northern portion slopes are more gentle because of deposition of very large quantities of glacial material, particularly in the valleys. From the two railroads which serve the area, the Pittsburgh & Fort Wayne and the Pittsburgh, Lisbon & Western, spurs can readily reach locations along the valley courses or can take advantage of the deep ravines which lead to the uplands. This district in the past has probably been the largest coal producer of the quadrangle and will continue to have a large output for some time, but it has its most promising future in the development of the clay industry. Building stone is also available in the southern portion, although none is now shipped. No limestone of importance is exposed. Oil and natural gas are produced and promise further wealth.

GENERAL GEOLOGY.

Stratigraphy.

The exposed Carboniferous rocks of the western district consist of about 150 feet of the Conemaugh group and about 200 feet of the Allegheny. Over these occur later glacial and fluvial deposits whose thickness is variable. The Conemaugh succession is shown on pl. IX and the coal intervals on pl. VI. Although the stratigraphy apparently conforms closely to the general section for the quadrangle, the strata are imperfectly exposed for study except at or near the more prominent coal horizons. In general the Mahoning, Lower Freeport, and Lower Kittanning sandstones seem to be present. The Butler horizon is commonly occupied by shale except in the southwestern corner of the district.

Structure.

The structure of this district is especially favorable for mining operations. The most prominent feature is the Darlington syncline, the axis of which is followed by the valley of Little Beaver Creek from New Galilee almost to the western limit of the quadrangle. From this axis the rocks incline upward to the northward, the inclination being about 25 feet per mile. This is indicated by the elevations of the Middle Kittanning coal: 925 feet near the southwest corner of the district, 942 at Cannelton, 975 at Darlington, 990 along Madden Run, 1015 near Enon Valley and 1080 along the northern boundary of the district. A minor syncline extends northward and eastward from the property of the State Line Coal Company to Honey Creek, and other minor structural irregularities are suggested by the local changes in elevation of the coals, as indicated in the following pages. These features, however, are too small and too poorly known from present data to be presented by the contour interval adopted, but can be readily determined locally by shallow drilling.

DISTRIBUTION OF BEDS AND LOCAL DETAILS.

This district, for convenience in description, may be regarded as divided into northern and southern sub-districts by the Pittsburgh & Fort Wayne Railroad.

Southern Sub-district.

Data were obtained south of the railroad from numerous mine openings, and from blossoms and outcrops exposed in the roads and in the deep ravines which dissect the area. Important strata are concealed extensively, however, by the glacial drift which forms a thin mantle on the hills, and by the deep alluvial deposits of the main valley. The dip although too slight and variable to be indicated with very great accuracy by the structure contours, is, in general, southwestward at about 15 feet per mile. The description proceeds eastward from the State line.

State Line to Coalbank Run. Just west of the State line at No. 399 the Upper Freeport coal, "No. 6," outcrops about 45 feet above the railroad or at altitude 1080 feet, and is 64 inches thick in the mine of the State Line Coal Company (Fig. 9, 17). Fifty feet higher the East Palestine coal, "No 7", is 26 inches thick (Fig. 9, 4), and overlies a bed of fire clay 3-4 feet or more thick, which is used by the National Fire Proofing Company. Southward at No. 398 this coal is at elevation 1110 feet at the bank of Mr. Whan, and is 37 inches thick (Fig. 9, 3). In the next ravine the outcrops of the Upper Freeport at the trestle of the State Line Coal Company, No. 397, are at altitude 1050 feet. The coal is 37 inches thick (Fig. 9, 16). The bed is 5—10 feet lower at another opening, No. 375, where the coal is 47 inches thick (Fig. 9, 7). A northeast-southwest line through this opening marks the axis of a mild synclinal fold from which the strata rise northward towards the railroad and also southward to an anticlinal axis passing near Mount Nebo school, at the road forks, No. 373, where the dip is reversed. Along this tract numerous bore records kindly furnished by Mr. Hugh Laughlin of

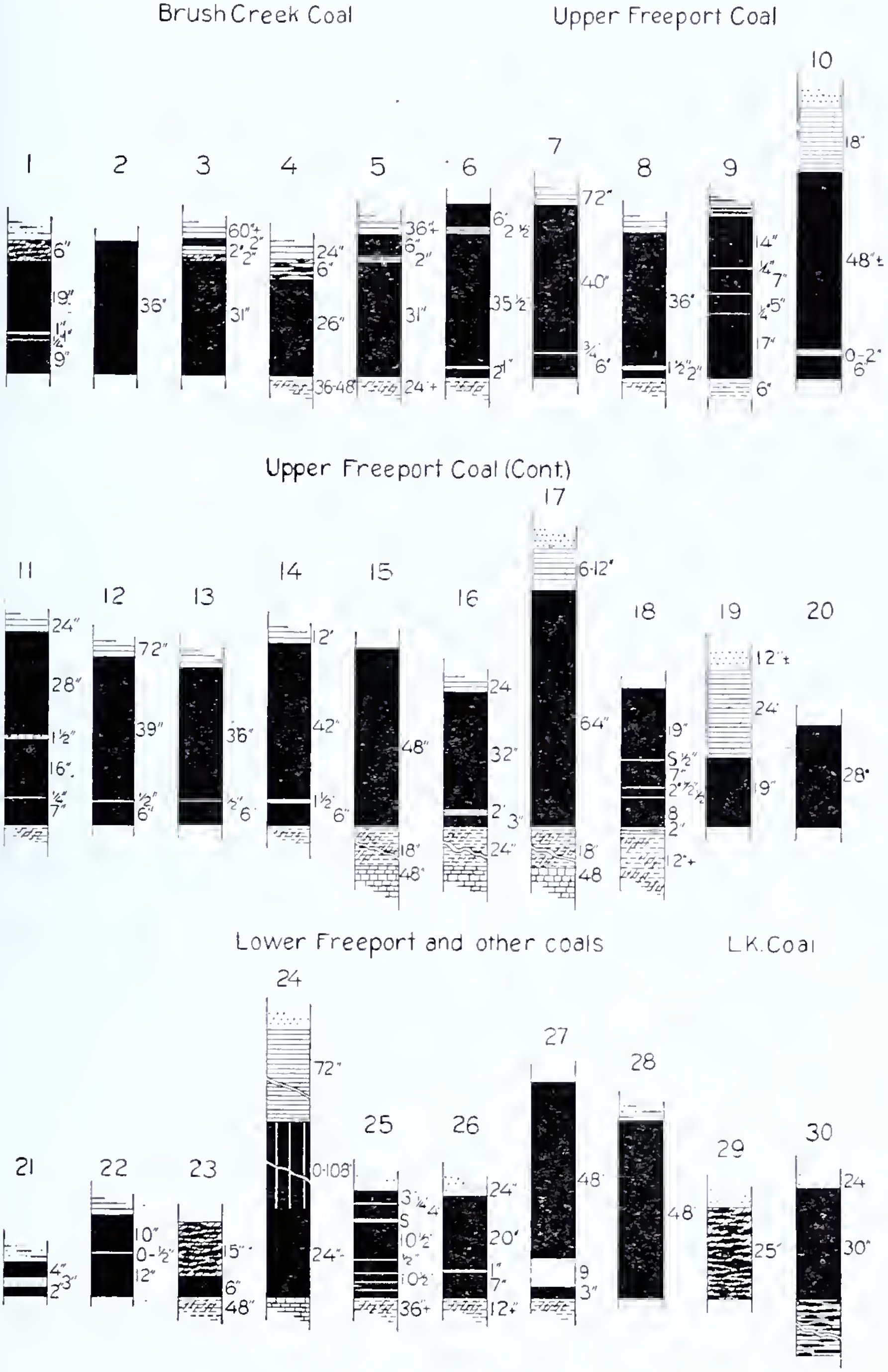

FIGURE 9. Coal sections in western district.

the State Line Coal Co., show the New Galilee clay and the East Palestine and Upper Freeport coals varying greatly in thickness. The Upper Freeport has a calculated altitude of 1090 in the test hole west of the school, but is actually absent because of local pre-glacial erosion. To the westward the Lower Freeport coal outcrops at elevation 1020 and is 85 feet higher than a blossom of the Middle Kittanning at No. 374, which, in turn, is 40 feet above the road forks. Along Little Beaver Creek at No. 371 an imperfect exposure of coal occurs, 30 feet higher than the railroad or 890 feet above sea level. It is overlain by shale 5 feet thick and a similar thickness of massive sandstone which is thought to represent the base of the 20-foot cliff exposed eastward in the railroad cut at No. 372. There again coal underlies it, but in thin streaks at railroad level (Fig. 9, 21). Knowledge of the full section of the coal and clay at No. 371 would doubtless help to identify this horizon. It seems probable that the Lower Kittanning coal occurs about 20 feet above the sandstone, and that the lower coal lies at or near the Scrubgrass horizon, which is not exposed elsewhere in this district. Possibly the coals under the two sandstones are different beds, and one or both may be the Lower Kittanning itself, or even the Clarion. To the northward section 67 (pl. IX) apparently shows the three Kittanning coals. The Lower Kittanning bed is at elevation 910 and shows great variation in section (Fig. 9, 29). The Middle Kittanning is 10 inches thick in the creek bed at elevation 955 feet and, because of southward dip, may possibly be identical with the bed observed at a small opening up stream (Fig. 10, 41). The latter is more probably the Upper Kittanning. There it is at elevation 975 and is 22 inches thick (Fig. 9, 22). It is 50 feet lower than the Lower Freeport which occurs near the ravine head. Along Coalbank Run at No. 377 an old opening at elevation 945 feet was probably on the Middle Kittanning coal, although possibly on the Lower Kittanning. In the side ravine to the westward the Lower Freeport, 6 inches thick, outcrops at elevation 1015 feet (Fig. 9, 23). The Upper Freeport is 50 feet higher at the air entry and man-way shaft of the State Line Coal Company, No. 376, where it is 39½ inches thick (Fig. 9, 8).

Coalbank Run to Dilworth Run. The area between Coalbank and Dilworth runs offers data from numerous openings on all coal horizons from the East Palestine to the Lower Kittanning, inclusive. The stratigraphy is represented by the Cannelton section (No. 69, pl. IX) and the local details are presented in the following table:

Coal and clay openings between Dilworth and Coalbank runs.

Map No.	Name of owner or operator.	Horizon	Coal.			Fire-clay.
			Altitude	Thickness Inches	See Figure	Thickness Feet
400	McCutcheon	East Palestine	1,125	39	Fig. 9, 5	2+
404		Upper Freeport	1,100			
403		Upper Freeport	1,100			
402		Upper Freeport	1,100	40	Fig. 9, 18	1+
401	Lafferty	Lower Freeport	1,060	6		
393	Lafferty	Upper Freeport	1,080	50	Fig. 9, 14	
392	Butts	Upper Freeport	1,105			
	McStay	East Palestine	1,150	36*	Fig. 9, 2	
396	Goff Kirby Co.	Upper Freeport	1,070			
	Goff Kirby Co.	Upper Kittanning	970			
394	Sterling Min'ng Co.	Upper Freeport	1,070			
395	Geo. Beresford	Upper Freeport	1,080	46*	Fig. 9, 15	
391		Upper Freeport	1,090	42½	Fig. 9, 13	
390		Upper Freeport	1,080			
389	Veon	Upper Freeport	1,075	45½	Fig. 9, 12	
388	Gishbaugher	Upper Freeport	1,100	53	Fig. 9, 11	
368	I. F. Mansfield	Upper Freeport	1,070	51	Fig. 9, 9	3 to 6*
378	I. F. Mansfield	Upper Freeport	1,070			
368	I. F. Mansfield	Lower Freeport	1,045			
368	I. F. Mansfield	Upper Kittanning	970	60	Fig. 9, 24	
368	I. F. Mansfield	Middle Kittanning	942	18	Fig. 10, 42	6+
368	I. F. Mansfield	Lower Kittanning	915	18½	Fig. 10, 31	6*
379	Burns White	Upper Freeport	1,098			
380	Burns White	Middle Kittanning	945	12+		
	Burns White	Lower Kittanning	920		Fig. 10, 32	4+
381		Middle Kittanning	945			

*Reported.

The Upper Kittanning is remarkably developed at Cannelton on the land of I. F. Mansfield where bituminous is overlain by cannel coal, the thickness being as much as 12 feet. Extensive mining and prospecting has shown that the deposit apparently occupies an old oxbow shaped channel. The length of the channel is about 3½ miles; its width, about 600 feet. Fettke[51] gives the following section:

Section at Cannelton.

		Ft.	In.
Mahoning coal		2	8
Clay		2	
Covered		38	
Upper Freeport Coal	Shale roof		
	Coal	4	
	Clay		1½
	Coal		2
	Shale floor		
Covered		114	
Upper Kittanning cannel bed		9	
Covered		50	
Lower Kittanning coal		1	7½
Fire clay		6	

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[51] Fettke, Chas. R., Oil Resources in coal and carbonaceous shales of Pennsylvania. Pennsylvania Topographic and Geologic Survey, Harrisburg, 1923, p. 56.

The cannel coal was occasionally as much as 12 feet thick along the middle of the channel, the thickness ordinarily being 7 feet or less. Cannel shale, up to 6 feet thick, occurred over the cannel coal at the middle of the channel. The maximum thickness of the coal obtained over a cross-section about 300 feet long. This was found to be much thinner as the bounding edges of the deposit were approached, where the roof and floor approached each other. A thin bench of bituminous coal, 6—2 inches thick, occurred beneath the cannel coal throughout the deposit. Thin lenses of bituminous coal were also interbedded with the cannel coal. As the edges of the deposit were approached the thickness of the bituminous coal increased, a maximum development of 3—3½ feet occurring.

Measurements of the Upper Kittanning coal follow:[52]

Section of Upper Kittanning coal at Cannelton.

Sandstone	Feet	
Cannel slate	0 - 6	
Cannel coal	0 - 12	maximum 15 ft.
Bituminous coal	0 - 3½	

Maximum thickness in any one section, 15 feet.

The name "Darlington" was given to this bed by I. C. White[53] but was more widely extended by him to a bed which is the Middle Kittanning. For this and other reasons the old name is not continued in this report.

In the hill west of Cannelton, No. 378, an old quarry face shows a massive sandstone 25 feet thick. It has medium sized grain and is of medium hardness, resembling the Mahoning bed over the Upper Freeport coal. The thin coal reported present at elevation 1100 beneath the sandstone, however, is probably the East Palestine seam. The hilltops in the vicinity show characteristic blossoms of the New Galilee clay, which is yellowish-brown, has flinty structure, and is about 90 feet above the Upper Freeport coal.

Dilworth Run to McCautry Run. The geology of the area, extending from Darlington northwestward to the railroad and lying mostly between Dilworth and McCautry runs, is known from sec. 69, pl. IX, which was obtained in the vicinity of Darlington[54], and from a few openings made for coal and fire clay. Near the head of Dilworth Run an old bank at No. 404 is at elevation 1100 and is in the Upper Freeport coal.

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[52] Second Geol. Surv. Rept. Q, p. 52.
[53] Pennsylvania Second Geol. Survey, Rept. Q, p. 51.
[54] Pennsylvania Second Geol. Survey, Rept. Q, p. 230.

On the hilltop northwest of this place the Beaver Finance Corporation is conducting a stripping operation on the East Palestine coal. This coal, under 8 - 30 feet of cover, is here 30 - 36 inches thick separated from a bottom bench 6 inches thick by 2 inches of bone. Only the upper bench is removed. The Upper Freeport bed was also worked near Mr. Dilworth's at No. 405, where its altitude is 1095 feet, and farther southward at No. 386, where it is 10 feet lower and is reported to be 56 inches thick (Fig. 9, 10). Below it at the last location, the Lower Freeport or "bung eye" is said to be 18 inches thick. At John Niceley's, No. 387, the Lower Kittanning is 930 feet above sea level and is reported to be 36 inches thick and to overlie fire clay 6 - 10 feet thick (Fig. 10, 34). About 15 feet above this coal the Middle Kittanning is said to occur 18-20 inches thick. Close estimates, however, indicate an interval of probably 25 feet between the old openings. Eastward the approximate horizon of the Lower Kittanning coal is indicated by an old dump at No. 382, whose elevation is 930 feet, and by a large blossom north of Darlington at No. 384. There the coal is at altitude 945, as at the mine of the Steffler and Brown Brick Co., No. 383, where it is 20½ inches thick (Fig. 10, 33), and is underlain by fire clay 6 feet thick. The Middle Kittanning or "18-inch" is 30 feet higher at this place (Fig. 10, 43). Half a mile northwestward from Darlington an old dump at about 1015 feet above sea level shows coal fragments possibly from the Upper Kittanning or Lower Freeport horizon.

McCautry Run to Madden Run. The area between McCautry and Madden runs contains a number of old coal openings and blossoms, whose relations are not everywhere clear. There is some doubt about the identity of the coals which occur just north of Darlington in section 70 (pl. IX). The lowest bed is probably the Upper Kittanning and the bed near the school which has heretofore been regarded as the Upper Freeport,[55] is the Lower Freeport. It is at elevation 1085 and is 30 inches thick (Fig. 9, 25). It is approximately 50 feet below the outcropping Upper Freeport limestone and 100 feet lower stratigraphically than the East Palestine coal which outcrops along the ridge road and is open on the farm of the Walter's Heirs, No. 385, at elevation 1175 feet. It is 36 inches thick (Fig. 9, 1). One-fourth mile northeastward from this latter point a blossom of fire clay at elevation 1125 feet probably represents the Upper Freeport horizon, and a coal blossom 40 feet below, the Lower Freeport. Farther westward a limited area is underlain by the East Palestine coal. At No. 406 it is mined by Mr. Pickles, at elevation 1155 feet, and at No. 407 by Mr. Madden at the same level. There the coal is 47 inches thick (Fig. 9, 6). Eastward a quarter of a mile, at No. 408, the Upper

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[55] Pennsylvania Second Geol. Survey, Rept. Q, p. 237.

Freeport is 19 inches thick (Fig. 9, 19), and 1110 feet above sea level. At No. 410 two old coal openings on the Wefing farm at elevations 1010 and 1095, probably indicate the horizons of the Upper Kittanning and Lower Freeport, respectively. The Lower Freeport sandstone is conspicuous there in the road about 40 feet thick and is quarried for local use a short distance up the run, where the face is 25 feet high.

Madden Run to railroad. The stratigraphy of the hills between Madden Run and the railroad is indicated by section 71, (pl. IX). Southward from Enon Valley, 1 mile, an old opening on the Madden farm, No. 409, is at elevation 1105 and is on or near the Lower Freeport horizon. A mile to the eastward, on the McGeorge place, No. 411, the Middle Kittanning was formerly opened about 990 feet above sea level and is reported to be 24 inches thick (Fig. 10, 44). It has the same level on the Greer farm, at the base of section 71. Twenty five feet lower the Lower Kittanning blossoms above an old quarry which is on the Lower Kittanning sandstone. Westward, the Lower Kittanning occurs at elevation 985 feet at an old bank and is 23 inches thick (Fig. 10, 35). Near the hilltop to the north the Lower Freeport coal is 28 inches thick (Fig. 9, 26), at Mr. Johnson's bank, and is at elevation 1110 feet. Fifty feet higher, on the Wells place, the Upper Freeport was seen 3 feet thick in partial exposure under a ledge of Mahoning sandstone 20 feet thick. The coal is reported to be

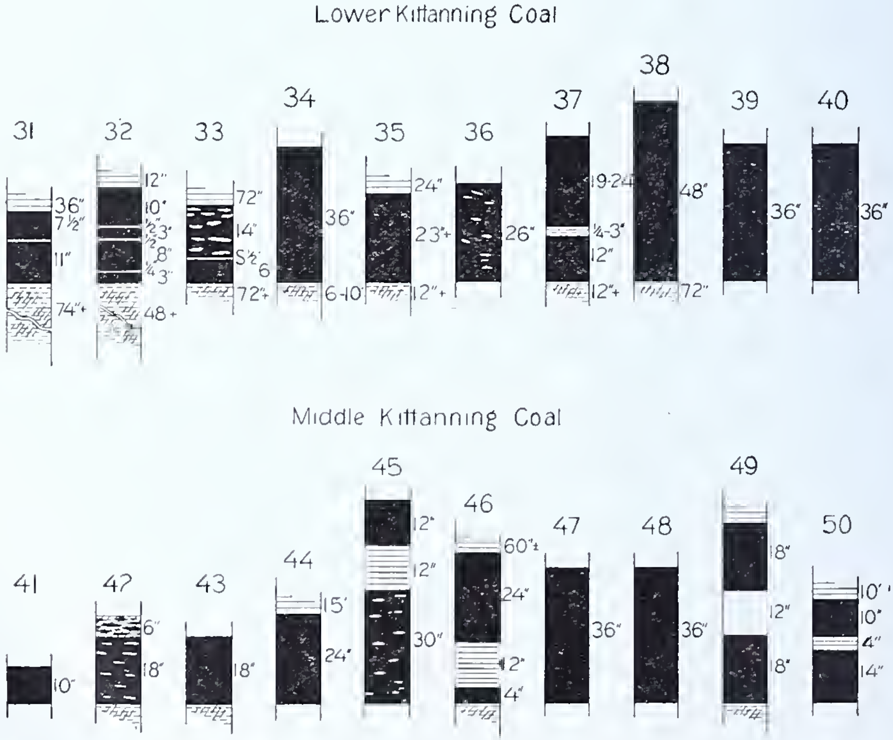

FIGURE 10. Coal sections in western district.

6 feet thick. Between this point and Enon Valley on the McGeorge farm, the Lower and Middle Kittanning coals were once opened. At No. 413 the Lower Kittanning bed is 5 feet above the railroad, or at elevation 980 feet, and is reported to be 26 inches thick but somewhat sulphurous (Fig. 10, 36). Above it, 35 feet, the Middle Kittanning coal is said to be 54 inches thick, but to contain a 12-inch parting (Fig. 10, 45). Southward, at No. 412, an old quarry shows the Freeport sandstone in a 15-foot face. It is a fine-grained, blue-gray rock and is at elevation 1075 feet.

Northern Sub-district.

In the area north of the railroad glacial drift and alluvium conceal outcrops over large portions of the sub-district and consequently both correlation and study of structure are unsatisfactory. The stratigraphy is illustrated by sections 72 and 74 (pl. IX).

Northwest of Enon Valley at No. 414, the Middle Kittanning coal in Mr. Miller's bank is at altitude 1015 feet and is reported to be 40 inches thick but to contain a 12-inch parting (Fig. 10, 46). Westward at No. 415, a coal 28 inches thick, reported in Joseph Bringman's well at elevation 1110, is probably the Upper Freeport (Fig. 9, 20). Along the Little Beaver, the old Slemmons shaft at No. 416 found the Lower Kittanning coal 34 inches thick at 32 feet depth or 960 feet above sea level (Fig. 10, 37).

Eastward one mile six test borings have been made on the farm of Powers' Heirs, No. 417, and the logs were furnished to the Survey. The location of the holes on a terrace is indicated by the map, and section 72½ (pl. IX)is representative of the strata drilled through. A surface deposit 4 to 75 feet thick was encountered in the holes, and the Middle Kittanning coal was absent through erosion in three and the Lower Kittanning in two of the locations. Three coals were found, presumably Middle Kittanning, Lower Kittanning, and Brookville. The top bed, in three holes, was 24, 31, and 36 inches thick (Fig. 10, 47) ; the second, in four holes was 12, 30, 37, and 48 inches thick (coal sec. 38, Fig. 10), and the lowest bed was 17, 32, 42, 44, 46, and 49 inches reported present at Enon Valley, but the Brookville in one record has 6 inches of bone at the bottom, and in another a 9 inch "rock" divides the bed into lower and upper benches which are respectively 3 and 48 inches thick (Fig. 9, 27). The Lower Kittanning clay is reported to be 6 - 10 feet thick with its bottom portion, as usual, harder than the top. One record shows the Lower Kittanning sandstone as being 25 feet thick, and a "hard rock," possibly the Vanport limestone, 40 feet below the Lower Kittanning coal and 45 feet above the Brookville. It would appear that one or more of these beds is commercially workable provided transportation could be obtained. The Lower Kittanning coal and clay could probably be mined together. The beds appear to be flat or with gentle southwest dip.

Near Honey Creek Creamery, an old quarry, No. 418, shows the Lower Freeport sandstone to be 20 feet thick. Northward the Middle Kittanning coal, where once drifted upon at the roadside, is at elevation 1035 feet. On the Riddle farm to the northeastward, No. 419, an old bank on the same coal is about 35 feet higher, and below it, 35 feet, a strong seep indicates the place of the Lower Kittanning. These beds are said to be about 3 feet thick in an old well at that place (Fig. 10, 39, 48). Northward half a mile at No. 420, the Middle Kittanning coal is at elevation 1065 feet on the Gilmore farm, and is reported to be 48 inches thick but broken by a 12-inch parting (Fig. 10, 49). In section 74, on the McAnlis place, the bed is 28 inches thick, the parting being 4 inches (Fig. 10, 50). It is at altitude 1060 there. The Lower Kittanning is 25 feet lower and is reported to be 36 inches thick (Fig. 10, 40). About 75 feet above the Middle Kittanning, the Lower Freeport was once opened on the McGehan place to the southwestward and is said to be about 4 feet thick under a sandstone roof (Fig. 9, 28). Half a mile to the westward a coal was reached 58 feet below the surface in an oil well on the Walter Fox farm. The elevation of the coal was about 1125 feet. The bed was probably the Upper Kittanning, although possibly the Lower Freeport. A coal 5 feet thick reported about 300 feet lower, is probably near the Mercer horizon. Northwestward, at No. 422, the Middle Kittanning makes a conspicuous blossom in the road 45 feet below Mr. Raney's gas well or at elevation 1080 feet. It is overlain by brown shale 20 feet thick. To the westward a coal blossom at No. 421, probably represents the Lower Freeport bed. Its position is about 10 feet above the road corner to the west, or 1160 feet above sea level.

ECONOMIC SUMMARY OF WESTERN DISTRICT.

Coal.

General discussion. Coal occurs at 8 exposed horizons in this district, as shown by the stratigraphic sections, and in the past has constituted the principal mineral resource. Future production will doubtless be large, but chiefly in connection with the development of the clay industry. The seam still most valuable for coal alone is the Upper Freeport. Other beds which may prove locally workable alone or have auxillary value in connection with the clays of the region are the East Palestine, Lower Freeport, Upper, Middle and Lower Kittannings. The notes on mining methods and the coal analyses, given on later pages refer in part to this district.

Upper Freeport coal. (No. 6, Sterling). The varying thickness and structure of the Upper Freeport coal at the places shown by numbers on the map is indicated by sections on Figure 9. The coal is thin or absent, locally, but under a considerable area measures from 40 to 72 inches, averaging, perhaps, 45 inches. Here it is separated by 1 to 4 feet of shale from the overlying Mahoning sandstone and by 1 to 2 feet of fire clay from the underlying limestone. There is commonly 4 to 12 inches of draw-slate. The coal is reported to be excellent for raising steam, but contains some impurities, especially near the base, where a somewhat persistent band of clay occurs from 2 to 8 inches above the floor and measures up to 2 inches thick. Other thin streaks of clay and "sulphur" occur 18 to 36 inches above the floor, but are local features. The coal usually becomes thin under a sandstone roof, but also where the roof shale is still present. Its irregularity has been well shown by drilling in the vicinity of Mt. Nebo school, where the thickness varies from 45 inches to nothing within 175 yards. This condition makes it impossible to state the area underlain by a workable thickness. A large proportion of the bed has already been removed from the area west of Dilworth Run, though several hundred acres remain. Between Dilworth and Madden runs many acres are underlain by the Upper Freeport horizon and though the bed is reported unreliable near Darlington[56] this area has probably never been tested adequately to warrant its condemnation.

East Palestine coal (No. 7, Three-foot, Brush Creek). This coal is best known from operations on it by the National Fire Proofing Company, the Beaver Finance Corporation, and by small coal banks to the east. Data are also furnished by numerous drill holes of the State Line Coal Company. The sections in Figure 9 indicate the thickness and structure of the bed at the localities shown on the map by numbers. The bed varies from 32 to 47 inches thick, and has a shale roof and thick fire clay floor. The top 8 inches of the coal is bony, containing thin streaks or bands of shale. Below this there occurs 26 to 36 inches of clean bright coal of excellent quality, reaching to the floor, or locally interrupted by a band of shale, one inch thick, from 2 to 9 inches above the base. As several of the test holes referred to show 24 to 33 inches of coal and 4, 8 or even 12 feet of underclay, the horizon warrants prospecting in the hill areas of this district southward from Madden Run, especially for the combined clay and coal.

Lower Freeport coal (No. 5, Bung Eye). The sections of the Lower Freeport coal obtained in this district are shown on Figure 9 and vary from 6 to 48 inches in thickness. The persistence of the horizon is further attested by numerous blossoms and by the four test holes of the State Line Coal Company, which reached to it, and show coal from 9 to 27 inches thick. While variations in thickness are considerable, and partings are locally present, it is possible that portions of the Lower Freeport area may show coal of value, along or in connection with operations on associated beds of coal or clay.

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[56] Pennsylvania Second Geol. Survey, Rept. Q, p. 230.

Upper Kittanning coal. (Cannel bed, No. 3 A, Darlington). Apparently thin bituminous coal at this horizon is widely present, but thickening is restricted to local deposits of cannel coal above the bituminous. The Cannelton area still contains much valuable cannel coal which was left in early operations, and it is always possible that drilling will reveal other similar deposits at this horizon.

Middle Kittanning coal. The accompanying sections of the Middle Kittanning coal (Figure 10) are mostly reported and probably are not altogether accurate. They indicate that the bed ranges from 10 to 54 inches in thickness, but that a thick parting of clay or shale which is frequently present renders the coal worthless locally. The roof is apparently always shale and the floor a fire clay, locally containing considerable iron. The coal itself is reported to be excellent and may prove of accessory value with the Lower Kittanning coal and clay, but it is impossible to say which portion of the large area underlain by this is most promising for prospecting.

Lower Kittanning coal. The measured and reported sections of this bed (Figures 9 and 10) show coal ranging from 18½ to 36 inches, overlain usually by shale and underlain by thick refractory clay. The coal is locally free from visible impurities but more widely has a slate parting about 12 inches above the floor, and in some places other thin bands of clay and patches of "sulphur." As the horizon of this seam underlies many acres in this district and can be easily reached by surface cuts or shallow shafts it especially warrants wide prospecting for itself alone or for the coal and clay combined.

Clay and Shale.

General discussion. The most valuable mineral resource of this district for some years will probably be its clay material. Refractory and probably stoneware clay occurs under the Lower Kittanning coal and an excellent clay for fireproofing and tubular ware lies under the East Palestine coal. Probably 200 tons of clay are now mined daily in this district. In addition several coal horizons will probably yield valuable clay locally, while the flood plain and terrace clays may be utilized and shale horizons developed for use alone or with other materials for building and paving brick. The following notes are supplemented on later pages by descriptions of mining and manufacturing methods.

Fire clay.

Lower Kittanning fire clay. The clay beneath the Lower Kittanning coal promises to be the most important mineral resource of this district, since it appears to be uniformly thick and of good quality and occurs near railroad level. It is shipped raw from the Mansfield property at Cannelton and by Burns White a short distance eastward, while at Darlington it is manufactured into brick by the Steffler and Brown Brick Company. At these mines the exposed clay varies from 4 to 6 feet while it is reported to be as much as 10 or 14 feet in total thickness. Elsewhere in the district at local coal banks it is said to occur in commercial quantity. The top 3 feet is soft and plastic while the remainder is hard and siliceous. The raw clay is from cream to brown in color and the burned ware gray, buff or red according to the method of burning and the admixture of other clay or shale. Its exact refractory quality was not learned, though it is commercially shipped as a fire clay. This horizon warrants further prospecting all around the district wherever transportation facilities are favorable.

East Palestine fire clay. The clay under the East Palestine coal is utilized by the National Fireproofing Company near East Palestine, Ohio, for making fireproofing, conduits, sills, drains, etc. The soft clay constituting the top three or four feet is mainly used though the lower siliceous portion is also valuable. This clay was found from 2 to 9 feet thick in borings near Mt. Nebo school and is probably valuable under much of the area which is underlain by its horizon.

Other clays of possible refractory value. All of the clay horizons shown in the stratigraphic sections may locally offer clay of value alone or in connection with the Lower Kittanning or East Palestine beds. Of these clays the Upper Freeport, Lower Freeport, and Middle Kittanning are most likely to prove satisfactory. The New Galilee clay also warrants testing since in the adjoining district it appears to be a flint clay of promise. Here it is perhaps too ferruginous to be refractory. The Upper Freeport clay at the State Line Coal Company's mines has been worked in the past as an auxillary product, through commonly only 2 or 3 feet thick.

Alluvial clays. The stream bottoms of this district contain extensive deposits of sandy clay, nowhere utilized at present, but doubtless usable for common brick, especially by mixing with fire clay or shale.

Shale.

The shales occurring over the Lower Kittanning coal are doubtless valuable here as they are in adjoining districts, and would probably make building or paving brick perhaps alone or with admixture of fire clay. Other shale horizons are shown by the stratigraphic sections, but those near fire clay horizons are most likely to be valuable, because of their accessibility for mixing purposes.

Building stone.

There is at present no production of building stone in this district except for local use, though good dimension stone occurs at several horizons. Near Cannelton the sandstone above the East Palestine coal is 20 feet thick and was formerly quarried and lowered to the railroad by an incline. South of Enon Valley a quarry shows 20 feet of thick bedded stone, while east of the town, a 15-foot face is exposed at an old stripping. These are exposures of the Lower Freeport sandstone. Southeastward the Lower Kittanning sandstone is 10 feet thick. North of Enon 20 feet of excellent heavy stone occurs. As future operations can be best carried on close to transportation a favorable locality appears to be the hilltop between Cannelton and Darlington, where stripping of the East Palestine and Mahoning beds should be easily accomplished and should yield a massive, medium-grained quartz sandstone of medium hardness and good dimensions. The rock is grey to buff in color where freshly exposed. Another favorable place occurs along the railroad near Elders mill, where stripping would doubtless show 20 feet or more of easily accessible grey stone of sound character and massive or thick bedding.

NORTHWESTERN DISTRICT.

Introduction.

The district which occupies the northwest part of the quadrangle (fig. 3), has not been highly developed because of its hilly character. Present commercial production of mineral resources is restricted to the northern area which is reached by railroad spurs, and future output in large quantities is apparently limited to the borders of the district, which offer the possibility of railroad transportation facilities. The mineral deposits include coal, clay, shale, limestone, sandstone, sand and gravel, oil and gas. The limestone is very extensively worked. Proper examination of the clay and shale horizons will probably show large deposits suited for export and local manufacture. Notes on the oil and gas production are given elsewhere.

The northwest district may for convenience of description be divided into north and south portions by the valley of Hickory Run from the mouth nearly to Mount Jackson, and thence southward to Honey Creek.

GENERAL GEOLOGY.

Stratigraphy.

As the Carboniferous rocks of the northwest district are concealed for the most part by deposits of drift on the hills and alluvium in the valleys, their stratigraphy is difficult to solve, and can be understood only through application of data obtained in other districts. The general columnar section on pl. VI, together with the local sections pls. VIII and IX offer all the evidence available.

The exposed rocks include 210 to 250 feet of Allegheny strata, beginning at the Lower Freeport coal; and about 280 feet of Pottsville beds, reaching 20 feet below the Sharon coal horizon. The coals observed are the Lower Freeport, Middle and Lower Kittanning, Scrubgrass, Clarion, Brookville, Homewood, Upper and Lower Mercer. Quakertown and Sharon. The Lower Freeport sandstone is exposed only in the vicinity of Mountair. A development of the same or another bed occurs above the Middle Kittanning coal between Hickory and Edward runs; elsewhere, brown shale seems to occupy this position. The Vanport limestone is thick in the northwest corner of the area and also north of Moravia, but measures only 1 foot at Mt. Jackson and in Edwards Run. The Pottsville may be sandstone or shale at the horizons of the Homewood sandstone and of the Upper Connoquenessing, but the Lower Connoquenessing is more persistent as a massive bed. Stratigraphic relations are further presented in the local notes which follow.

Structure.

The structure of this district is rendered obscure by the infrequent rock outcrops and the consequent doubt about stratigraphic intervals, especially in the Pottsville formation.

The general structure is that of a broad monoclinal slope covering most of the area but relieved by the Covert syncline and West Newcastle anticline already described. Local dips may be determined from the later presentation of detailed observations.

SOUTHERN AREA.

The description of the southern area proceeds from Hickory Run to Moravia and then to the south and west. Section 49 (pl. VIII) indicates the stratigraphy along the creek and the Homewood coal is exposed at Nos. 458 and 459 (Fig. 11, 35, 36). It has an elevation of 995 feet in Mr. Porter's bank at No. 456, and is 30½ inches thick (Fig. 11, 34). Section 48 (pl. VIII) was obtained on Mr. Brest's farm to the south. The Middle Kittanning coal is 19 inches thick (Fig. 11, 12) at No. 455, and is 1160 feet above sea level. The

Lower Kittanning is reported to occur 25 feet lower and to measure 24 inches here (Fig. 11, 20), but to thicken to 4 feet under the Hanna farm to the south (20a, Fig. 11). Two prospect openings on lower coals also occur at No. 455, separated by a sandstone 15 feet thick. In the lower opening at an elevation of 1020 feet, a 19-inch coal was observed (Fig. 11, 29) which probably represents the Brookville. Opposite the school in Mr. Brest's mine the Howewood seam is 42 inches thick, but contains impurities at the top and in the middle (Fig. 11, 33). Its elevation is 900 feet, and above it the Homewood sandstone is 30 feet thick. The Mercer limestone measures 1 foot thick in the ravine, 20 feet below the coal bank. Southward the Vanport limestone has an exposed thickness of 11 feet in an old quarry and lies 1075 feet above sea level. Section 47 (pl. VIII) was obtained here.[57] Near Moravia, where section 46 (pl. VIII) is exposed, the Upper Connoquenessing sandstone is 40 feet thick. The Lower Mercer limestone is 2 feet thick at No. 454, and is immediately underlain by a few inches of bony coal with a 4-foot fire clay (Fig. 12, 37), and 15 feet lower by another coal measuring 6 inches. The beds rise upstream. At No. 453 the Homewood sandstone occurs as a 20-foot cliff underlain by a one-foot coal and a light sandy fire clay about 5 feet thick, which appears to be valuable. The Upper Mercer coal here is 12 inches thick under a 12 inch limestone and with 5 feet of fire clay beneath. For a considerable distance along the creek intervals of 20 feet separate the Homewood, Upper Mercer and Lower Mercer coals, and they have about the same thickness (Fig. 11, 31, and 12, 40). The stratigraphy is confusing because of the resemblance of the Mercer horizons and the presence of a small roll which causes the creek to make two falls about 100 yards apart over the lower Mercer limestone. Higher along the run, at No. 452, the Vanport limestone and its immediately underlying coal each measure one foot in thickness (Fig. 11, 28) and resemble the Mercer beds, except for the presence of "cone-in-cone" structure in the Vanport limestone. It occurs here at an elevation of about 1015 feet, or 70 feet higher than the nearest exposure of the Homewood coal and 120 feet lower than the Middle Kittanning opening at the top of the section on the Lusk farm, where that bed is 21 inches thick (Fig. 11, 11). The Lower Kittanning appears to be exposed in the road to the southeast about 35 feet lower than the coal bank, but this may still be the Middle Kittanning, since there is a considerable dip here to the south and west. In the Robinson bank to the west at No. 451, the Middle Kittanning bed lies 30 feet lower than at Mr. Lusk's or at 1105 feet above sea level. It is 24 inches thick (Fig. 11, 10). It continues to dip southwestward and is at 1090 feet or lower in the 112-foot well on the John Kyle farm at No. 450. This well begins at

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[57] White, I. C., op. cit. Report QQ, p. 139.

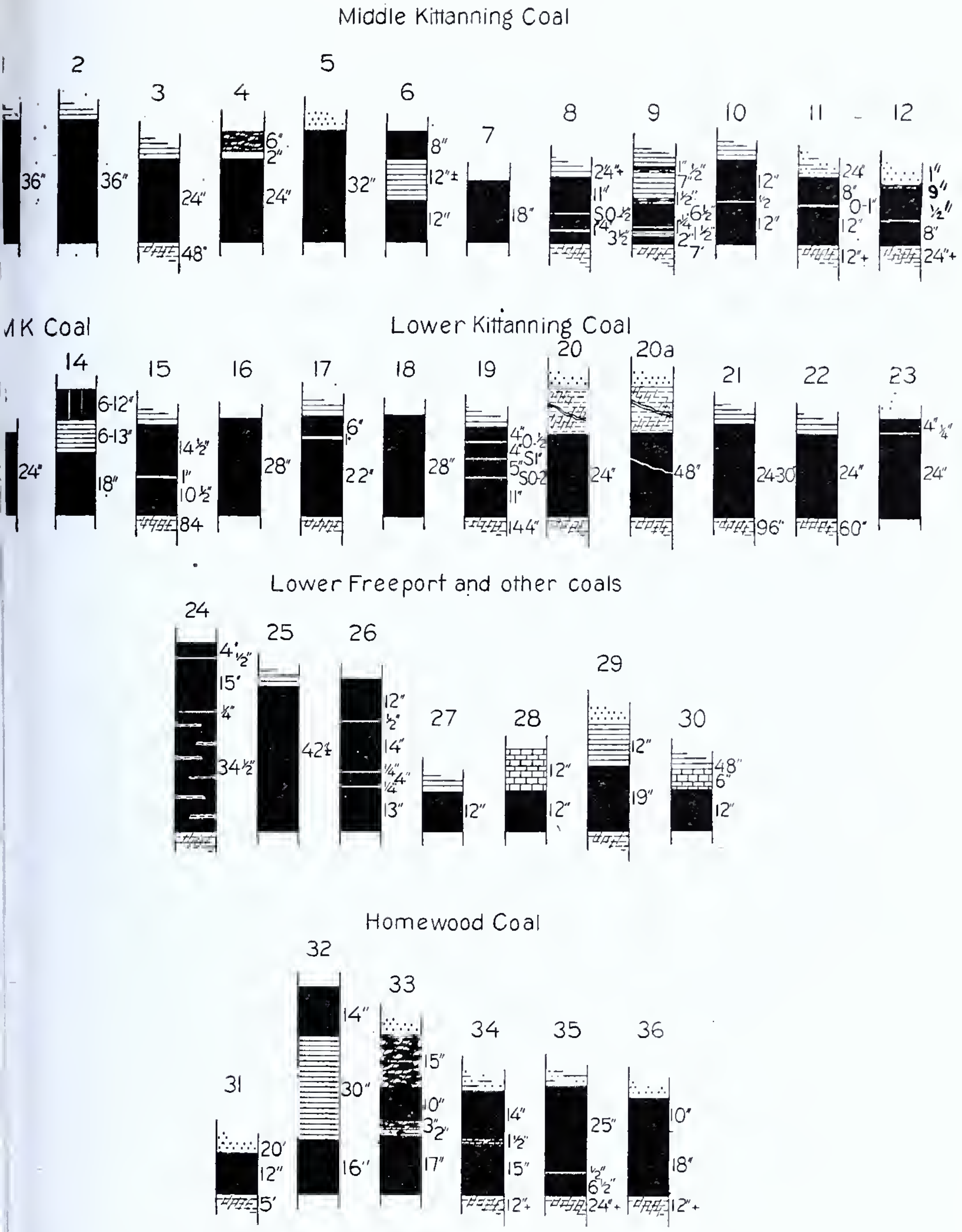

FIGURE 11. Coal sections in northwestern district.

about the horizon of the Lower Freeport coal, passes 8 feet of clay, 60 feet of sandstone and 44 feet of shale and probably obtains its water from over the Middle Kittanning bed.

Several exposures of the Lower Freeport and of the Kittanning horizons occur in the area west and south of Edwards Run. At No. 440 the Middle and Lower Kittanning were once opened on the Henderson farm at elevations of 1135 and 1105, respectively. The higher seam is reported to measure 32 inches (Fig. 11, 4), and to have a very different section from that to the north at No. 449 (Fig. 11, 9). The lower seam is reported to be 28 inches thick (Fig. 11, 16). Southward at No. 439 a one-foot outcrop of the Lower Freeport coal occurs over its accompanying limestone, in the road above Mr. Swishers house at an elevation of 1165 feet. There appears to be an old coal bank to the north, about 50 feet lower. The Middle Kittanning coal would normally lie about 80 feet beneath the Lower Freeport.

From Mountair to the southeast and south a number of old coal openings indicate the elevation of the Lower Freeport and Kittanning seams. The intervals are shown by sections 73 and 72 (pl. IX). At Miller's bank No. 438, the Lower Freeport is 44 inches thick and has an altitude of 1150 feet (Fig. 11, 26). At No. 437 a ravine exposes the same bed 42 inches thick (Fig. 11, 25), although at the top of section 73 at Mr. Witherspoon's it measures 54 inches (Fig. 11, 24). At Mr. McCown's, No. 436, the Middle Kittanning occurs at elevation 1075 feet and is reported to be 24 inches (Fig. 11, 3). Across the road to the west in Mr. Patterson's bank the Lower Kittanning measures 26 inches (Fig. 11, 16), and is at elevation 1050 feet. Beneath it a 7-foot fire clay is reported. A blossom of the Lower Kittanning occurs at No. 435, at an elevation of 1055 and the Middle Kittanning 35 feet higher at an old opening. To the east old banks on the Middle Kittanning occur at Nos. 433 and 434, about 1100 feet above sea level. Across Beaverdam Run, at No. 432, the same coal is at elevation 1055 feet, in a road blossom, and the Lower Freeport coal and limestone are 90 feet higher in the hilltop. At the base of section 72 in an old bank the Middle Kittanning is at elevation 1040 feet, and is reported to be 36 inches thick (Fig. 11, 2). To the west at No. 431 an opening on the Prescott farm shows 18 inches of the Middle Kittanning in partial exposure at altitude 1030 feet (Fig. 11, 1). It is said to be 36 inches thick. An old shaft beginning 30 feet lower is said to reach the Lower Kittanning at a depth of 10 feet.

NORTHERN AREA.

The description of the northern area proceeds eastward and southward from outside the quadrangle at Quakertown Falls where section 54[1] (pl. VIII) shows the lowest exposed Pottsville beds of this region. The Sharon coal is represented by thin streaks embedded in bituminous shale.

In sections 54, 53 and 52[2] the Vanport limestone measures 14, 19, and 18 feet respectively. Coal sections Nos. 38, 43, Fig. 12, indicate the Lower Mercer and Upper Mercer coals in section 53, as described by White.[3] Coal sections Nos. 39, 44, Fig. 12, indicate the Lower Mercer and Quakertown coals in section 54, described by the same author.[4]

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[1] Pennsylvania Second Geol. Survey, Rept. QQ, pp. 189-193.

[2] Pennsylvania Second Geol. Survey, Rept. QQ, pp. 189 193.

The Upper Mercer coal in section 52 has an elevation of 950 feet and a thickness of 51 inches, but is bony at the top and below is broken into two benches by a 9-inch parting (Fig. 12, 42). In Section 51,[5] farther southeast, the strata have the relations indicated in pl. VIII and the Quakertown coal is 18 inches thick, though the railroad grading conceals much of the section. At No. 469 sand is excavated for shipment. Southward, at the top of section 51 on the W. A. Petrie farm, the Homewood sandstone is represented by massive blocks extending about 50 feet vertically. Below it occurs the Homewood coal locally absent but swelling to 14 inches.

Near the north margin of the quadrangle data are obtained from the Kittanning coals and the Vanport limestone. At No. 471, the Lower Kittanning coal has an elevation of 1140 feet and is 24 inches thick (Fig. 11, 22). Over it occurs 5 feet of brown shale and beneath it fire clay which is said to be more than 5 feet thick and was formerly shipped. Southeastward, at No. 468, the same coal lies 40 feet deep in a well on the Robert Davis farm, or at an altitude of 1130 feet. The John McCord well, No. 467, is reported to reach two coals within a depth of 101 feet. Evidently the horizon of the Lower Kittanning coal in this vicinity lies about 40 feet above the Vanport limestone, but it has been extensively removed by erosion and the limestone itself forms the surface immediately under the drift. It is quarried by several companies for flux and road ballast in pits lying about one mile north of the quadrangle, and extending about three miles east of the State line. Within the quadrangle the following table summarizes observations on this bed.

Vanport limestone in northwest corner of quadrangle.

Map No.	Name of operator or farm.	Thickness of stone in feet		Altitude of top. Feet	Overlying material	
		Total	Top (gray)		Character	Thickness in feet.
470	Miller	22*	18*	1,100	drift	4–20
472	Geo. Johnson	15	12	1,100	drift	5–25
473	Hoffmaster	19*	----------	1,125	drift	17*
466		--------	----------	1,120	drift	24*
465		--------	----------	1,135+	drift	30*
464	D. C. Hayes	19+*	----------	1,110—	drift	24*
462	Bessemer Limestone Co.	20-22	16	1,100—	drift	5–15
		--------	----------	1,115	shale	5–25
461	Wallace	5+	----------	1,105	none	----------

*Reported.

At Bessemer the shale overlying the limestone is manufactured into excellent paving block and building brick. It is also used in the manufacture of cement.

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[3] White, I. C., op. cit. Rpt. QQ, p. 191.
[4] White, I. C., op. cit. Rpt. QQ, p. 193.
[5] Pennsylvania Second Geol. Survey, Rept. QQ, p. 140.

West of Bessemer at No. 463, an old shaft on the Crum farm reached the Lower Kittanning coal at a depth of 10 feet, or an elevation of 1140. It is said to measure 22 to 28 inches (Fig. 11, 23), and to overlie a thick bed of fire clay. The well on Mr. Hayes place to the south reached a 4-inch coal at a depth of 20 feet or an altitude of 1180 feet. This is probably the Middle Kittanning seam.

South of Bessemer on the Wallace farm, No. 461, the Lower Kittanning is said to measure 24 to 30 inches and to overlie an 8-foot fire clay (Fig. 11, 21). Its elevation is 1150 feet. Above it an old stripping on the Middle Kittanning at an elevation of 1175 feet is said to have revealed a 32-inch bed broken by a thick shale parting into a top cannel coal and a lower bituminous bed 18 inches thick (Fig. 11, 14). Half a mile west the Lower Kittanning is exposed by stripping operations at a limestone quarry.

In the southwestern part of the area several openings and blossoms occur on the Lower and Middle Kittanning and the Lower Freeport coals. At No. 443 the Lower Freeport blossom occurs 20 feet below the road crossing or 1180 feet above sea level. It was once drifted upon here and is reported to be 12 inches thick under a roof of shale (Fig. 11, 27).

Southward the Middle Kittanning was reached in a test shaft at a depth of 15 feet or an altitude of 1080 feet. Farther east the stratigraphic relations are indicated by section 75, pl. IX. There the Lower Kittanning coal is 29 inches thick (Fig. 11, 17), and at elevation of 1070 feet at the mine of R. R. Saviers. In the ravine nearby, a 20-foot ledge of thick-bedded sandstone has been quarried for local use. Five feet below it or at an elevation of 1090 feet the Middle Kittanning coal was once opened and is reported to be 32 inches thick but broken by a thick shale parting (Fig. 11, 6). The Lower Freeport limestone occurs 100 feet higher near the junction of the lane and main road. At No. 442 an old bank on the Middle Kittanning has an elevation of 1105 feet (Fig. 11, 5), while further east at No. 441 the Lower Kittanning on the Gilmore farm is 25 feet lower and is reported to be 28 inches thick (Fig. 11, 18).

To the northwest, at an old opening on the Mayberry farm, No. 444, the Middle Kittanning is 1140 feet above sea level and is said to be 18 inches thick (Fig. 11, 7). The same seam on the White place, No. 445, is 15 feet higher and 20 inches thick (Fig. 11, 8). An old shaft sunk to the east, No. 446, is reported to have struck coal at a depth of 75 feet or an altitude of 975 feet. It was about 5 feet thick but contained a thick rock parting in the middle (Fig. 11, 32). The section as drawn is hypothetical, not actual measurements. This seam lies about 175 feet below the Middle Kittanning and at either the Brookville or Homewood horizon. At No. 447 a coal blossom occurs in the road beneath a 10-foot white sandstone, or at an elevation of 1140 feet. This is the Middle Kittanning. In the ravine to the east, No. 448, and old coal test boring on the Fullerton[1] farm reached three coals comparable to the Clarion, Brookville and Lower Mercer at depths of 90, 105, and 150 feet, respectively, and these measured 3, 3½ and 2 feet in thickness. (See sec. 78, pl. IX). A more recent boring in this vicinity verifies the intervals between the coals and shows the Brookville with a 4 inch band between upper and lower coal benches respectively 20 and 4 inches thick. The Clarion coal is only 6 inches thick. On the Wood farm, No. 449, the Lower and Middle Kittanning coals are mined by Henry Allshouse. They lie at elevations of 1110 and 1150 feet, respectively and measure 27 and 9 inches (Fig. 11, 19, 9). The Middle Kittanning bed has its rather characteristic thick parting of shale, and the Lower bed its conspicuous fire clay, reported here 12 feet thick.

At Mt. Jackson section 50 is exposed, descending from the Davidson farm where the Middle Kittanning coal is 20 feet below the road forks or at an altitude of 1140 feet. It is reported to be 24 to 30 inches thick (Fig. 11, 13). At No. 460, a 12-inch coal has been opened immediately below a 6-inch limestone which is the representative of the Vanport (Fig. 11, 30). The Clarion and Brookville coals are present and the Homewood coal occurs over a white, sandy fire clay, but the place of the Homewood sandstone appears to be occupied by shale. Above the bridge, near the base of the section, the Upper Mercer limestone is 18 inches thick and forms the ledge over which the creek falls. It is 980 feet above sea level and is underlain by a foot or less of bony coal (Fig. 12, 41). A small rise to the east exposes the Lower Mercer just below the bridge, only 5 feet lower than the upper falls. Downstream, at No. 459, the Upper Mercer has an elevation of 990 feet and is 30 feet below the Homewood coal, both at J. M. Kyle's bank where the latter is 28 inches thick (Fig. 11, 36) and at another opening further east, No. 458, where it measures 32 inches (Fig. 11, 35). Both of the Mercer limestones outcrop downstream between this point and the wagon bridge, but below that place only the massive Connoquenessing sandstones occur. Section 49 (pl. VIII) indicates a compiled section for this vicinity. Northward at No. 457 the Upper Connoquenessing sandstone is exposed 10 feet thick in a small quarry, but boulders indicate that the top of the bed lies about 30 feet higher or at 950 feet altitude. A coal bloom in the road a quarter of a mile to the west and 85 feet above the top of the sandstone lies at or near the Brookville horizon.

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[1] White, I. C., The Geology of Lawrence County, Pennsylvania Second Geol. Survey, Rpt. QQ p. 134, Harrisburg.

ECONOMIC SUMMARY.

Coal.

Eleven or more coal horizons are exposed in this district as indicated under Stratigraphy, and by the detailed notes and graphic sections. Five beds appear to have value for local trade and of these some may prove commercially important where within reach of transportation, especially if the accompanying fire clays prove good. In this respect the most promising bed is the Lower Kittaning.

Lower Freeport coal. The Lower Freeport underlies a small area north of Honey Creek along the State line, a hill between it and Mountair, and at the latter place several hundred acres. A limited distribution occurs also in the hill south of Beaverdam Run. The thickness of the coal where known, as indicated by sections 24 - 27, Fig. 11, ranges from 12 to 53 inches, but apparently the only occurrence of any value is in the vicinity of Mountair, where the bed is of local importance and over a considerable area exceeds 42 inches in thickness. The present workings may possibly be extended from Mountair northwestward under the hill 1½ miles distant, and also eastward about half a mile, but the roof may be poor and local erosion channels may cut out the coal.

Middle Kittanning coal. The sections on Figure 11 indicate the structure and thickness of the Middle Kittanning coal observed or reported at the localities shown on the map by numbers. The thickness of the bed varies from 18 to 32 inches and its quality is said to be excellent except where locally it is impaired by impurities. These occur in different parts of the bed. A thin parting of shale and "sulphur" is present in the middle of the coal in the area between Hickory Run and Edwards Run. A conspicuous band like that noted in other districts appears in three of the sections and is from 9 to 13 inches thick. Normally the roof is shale and the floor fire clay. The area underlain by this coal horizon is doubtfully indicated on the map because of the drift deposit, but it is extensive enough and good enough locally to warrant prospecting for domestic supply and in the vicinity of Mountair and southward where it may be reached by a railroad spur it may possibly prove of commercial value. At present small banks are operated on the Woods, Lusk, and Robinson farms.

Lower Kittanning coal. The sections obtained of the Lower Kittanning coal, shown on Fig. 11, indicate a thickness of from 24 to 29 inches at the places shown on the map by numbers. The coal is said to be very good, when the local impurities are excluded. Below Mountair a thin parting occurs near the middle of the bed; in several other sections partings of from ¼ to 1 inch are present, but in general they do not greatly lessen the value of the coal. The roof is shale and the floor a thick fire clay. The coal is mined for local use on the Patterson, Savier and Woods farms at map numbers 436, Sec. 75, 449, besides being open at other places. Shallow tests holes or surface cuts will readily reveal its thickness and quality. It is the most available coal of the district and may prove of commercial value, especially in connection with the underlying fire clay, where not too far from transportation facilities.

Homewood coal, Four-foot, Hickory Creek coal. The Homewood coal is mined for local use along Hickory Run at the Kyle and Wallace banks, Nos. 459, 461, and southeastward on the lands of Messrs. Porter and Brest, No. 456, section 48. It is exposed also in Edwards Run, and was reached in a shaft farther west. The accompanying sections (Fig. 11), indicate a thickness varying from 12 to 47 inches. The coal is of rather poor grade, being sulphurous and dirty, and locally shows a thick parting of shale. Where thick the roof is shale or bone, but along Edwards Run the bed is thin and lies immediately beneath the massive Homewood sandstone. The floor is a light-gray, non-plastic fire clay. Although the horizon of this coal extends under the whole district except where eroded in the deep ravines, the bed is probably very irregular in thickness and of no commercial value except possibly in connection with its underlying clay.

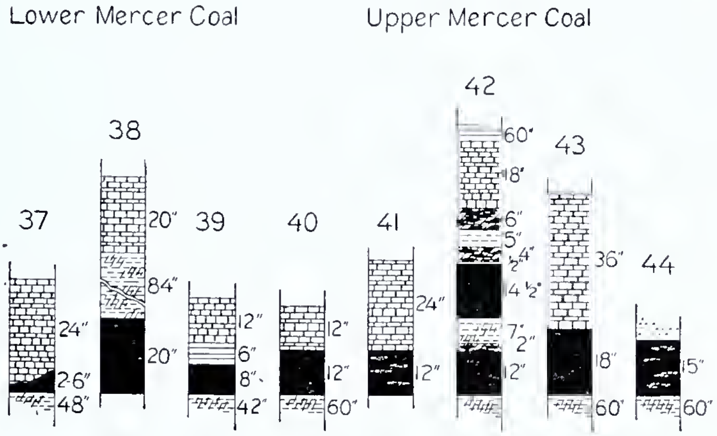

FIGURE 12. Coal sections in northwestern district.

Upper and Lower Mercer coals. Several sections of the Mercer coals are presented on Fig. 12 but indicate thin and comparatively worthless seams. The Upper Mercer is mined north of the quadrangle proper at Leeper's bank, but is full of impurities which interfere with economical working and limit the sale of the coal to local trade.

Fire clay.

The positions of the various coal beds which are underlain by fire clay are indicated by the accompanying maps and notes. Promising clays accompany the Lower Kittanning, Homewood and Mercer coals, and the other horizons are also worth examination.

As the Lower Kittanning clay is indicated 5, 7, 8 and 12 feet thick in the accompanying coal sections (Fig. 11), it probably is thick under much of the district and may prove excellent for refractory, structural, and domestic ware as it is in other parts of the quadrangle. It has been shipped from a bank near Hilltown. Its examination is especially desirable near Bessemer and perhaps also in the vicinity of Moravia, and along Beaverdam Run.

The Homewood clay is possibly highly refractory along Edwards Run and Hickory Run. It is free from iron, being gray or white, and is very siliceous and probably non-plastic. As it is locally at least 5 feet thick, it may prove of excellent value, especially in connection with the plastic clay of the Lower Kittanning horizon.

The Upper and Lower Mercer clays are also siliceous and perhaps non-plastic. A thickness of 4 and 5 feet is exposed in Edwards Run; and near Hilltown the clay above Lower Mercer coal is 7 feet thick and that below the Upper Mercer 5 feet thick.

Shale.

Several shale beds of the district are suited to the manufacture of building and paving brick, especially if mixed with fire clay. At Bessemer the shale above the Vanport limestone is from 5 to 25 feet thick and is successfully used by the Metropolitan Paving Brick Company, and the fire clay-shale beneath the limestone may be valuable. Other shales which may probably be utilized occur just above the Lower and Middle Kittanning coals, and may be of auxillary value to the Lower Kittanning fire clay.

Limestone.

The Vanport limestone is the most extensively worked mineral resource of the northwest district, yielding many hundred tons daily. The bed has commercial thickness in the northwest part of the quadrangle, where quarried, and under much adjoining property, according to well records. Elsewhere the bed is either very thin or is effectively concealed by drift. Other limestones in the district are the Lower Freeport and the two Mercer beds, but they are worthless.

Large quarries of the Bessemer Limestone & Cement Company and of the Pittsburgh Crucible Steel lie within the quadrangle proper, and more extensive workings in the area adjoining on the north. The

Dayton quarry north of Moravia is now abandoned. Additional notes on methods of quarrying and an analysis of the stone are given on later pages.

The Bessemer Limestone & Cement Company ships from the four large pits indicated on the map. The limestone measures 20 to 22 feet and occurs in beds which differ slightly in appearance and composition. In the following section No. 5, or the blue layer, contains considerable phosphorus and is not suited for flux but is used for ballast and concrete. The overlying gray stone is shipped for flux. No. 1 is said to run higher in phosphorus and No. 4 higher in silica than the other beds.

Section of Vanport limestone at Bessemer.

Bed.		Thickness in feet.
1	"Top"	3
2		3
3		4
4	"Rotten" and "Bull"	6
5	"Blue"	4
		20

In the Geo. Johnson quarry the top or gray stone is 12 feet thick and is shipped for flux. The bottom blue layer which measures 3 feet is not quarried.

The old Dayton works north of Moravia formerly produced stone for flux. The top gray bed varies from 5 to 18 feet and the blue layer measures about 2 feet.[1]

Sandstone.

Only two small sandstone quarries were observed in the district: one on the Upper Connoquenessing bed west of Mahoningtown, where the face measures 10 feet; and another near Honey Creek, in section 75, where the sandstone above the Middle Kittanning coal is 20 feet thick. The first of these quarries might be developed into a commercial enterprise as the total massive thickness appears to be as much as 40 feet. Other promising sites occur at Quakertown Falls and elsewhere north of the quadrangle proper.

Sand and Gravel.

Sand and gravel occur along the terraces of the large streams, especially near Covert, where sand has been dug and shipped, and along the bluffs north of the quadrangle.

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[1] Pennsylvania Second Geol. Survey, Report QQ, p. 139.

NORTHEASTERN DISTRICT.

INTRODUCTION

The area north of Connoquenessing Creek and east of Beaver and Mahoning rivers has contributed greatly to the wealth of the quadrangle, though the roughness of the surface has interfered with its highest commercial development. The upland rises from 400 to 500 feet above river level and is deeply dissected in the southern portion by narrow, flat-bottomed valleys with steep walls. Northward the slopes have been rendered more gentle by thick glacial deposits. Outlet for the products of the district has been obtained by means of the Baltimore & Ohio, Pittsburgh & Lake Erie, and Pennsylvania railroads. The Buffalo, Rochester & Pittsburgh Railroad has entered the northern part of the area. Much of the district can be reached only by long sidings laid along the hollows, but the deposits of limestone and accessory minerals, such as coal, clay, shale, and stone, will doubtless attract capital.

The easiest grades for the railroads are along the valleys of the main streams—Shenango and Beaver Rivers, Connoquenessing Creek and Big Run. It is only in the vicinities adjacent to these streams that the smaller tributaries have exposed the commercially valuable strata sufficiently to encourage commercial development. The balance of the district is so thoroughly covered by glacial material as to mask the underlying rocks and leave few clues as to the extent, position, or value of the strata which are, in other places, of commercial value.

The main streams have caused the uniform grades so desired for railroad traffic. The grades of the tributaries, however, are so steep as to prohibit easy access to the higher portions of the district. For these reasons the borders of the main streams and their tributaries have been the site of most of the commercial developments.

The valleys of the tributaries and the areas between the valleys, form convenient natural portions or subdivisions for purposes of description. The district will therefore be described by valleys and interstream areas.

GENERAL GEOLOGY.

Stratigraphy.

The exposed Carboniferous rocks of this district include about 265 feet of the Allegheny group and 160 feet of the Pottsville. They are masked by a thick layer of glacial and fluvial deposits and are difficult to identify except near outcrops of the Middle Kittanning coal and Vanport limestone. The accompanying local sections (Nos. 17-28, pl. VII) indicate observed exposures and the general columnar section (pl. VI) aids in their interpretation. Coal occurs at eleven horizons; Lower Freeport, Upper Kittanning?, Middle or Lower Kittanning, Scrubgrass, Clarion, Brookville, Homewood, Upper and Lower Mercer and Quakertown. The intervening beds in the Allegheny group are notably shaly. In the Pottsville, massive sandstones are prominent. The Vanport limestone exhibits its peculiar habit of varying greatly in thickness within short distances. Further stratigraphic peculiarities, especially of the Pottsville members, are presented under the general chapter "Stratigraphy" on pages 47-57, and in the following pages.

Structure.

In the southern part of this district the rocks have a general dip of about 40 feet per mile to the southwestward but local variations occur, as shown by the structure contours. In the northern and northwestern parts the dips are determinable only with difficulty, but are probably approximately as indicated and as described under "Structure," page——. In a general way, the structure is highest near the swamp north of Energy, the strata dipping away to Beaver River and Connoquenessing Creek.

Area East of Squaw Run.

Several Pottsville beds outcrop in the extreme southeast corner of the area. At the mouth of Slippery Rock Creek, at No. 66, a 15-foot cliff just above railroad level represents a top portion of the Upper Connoquenessing sandstone, which has been eroded from that member in the area just to the west. Northward the Lower Mercer limestone is underlain by thin coal, at No. 67, and is 15 feet above the old railroad siding or 880 feet above sea level. The same strata are exposed at the same level, and the relations made clear at No. 68 where section 18 (pl. VII) was measured. The same horizons are less perfectly exposed in the hill road to the east, but a southeast dip makes them lower. The Lower Mercer coal at No. 65 is 10 feet above the bridge or 840 feet elevation. Thirty feet higher occurs the Homewood coal and 60 feet above that, or 20 feet below the bend in the road, the Clarion coal blossom appears below a blue-gray sandstone. The base of the Vanport limestone is 50 feet higher than the Clarion and 70 feet below the Lower Kittanning coal and fire clay. Directly above the latter, 45 feet, at No. 69, the Middle Kittanning was once opened at an elevation of 1100 feet. Farther north at No. 100 and 102 the top of the Vanport at the road forks has an altitude of 1040 feet, while the Lower and Middle Kittanning coals to the south are respectively 50 and 70 feet higher. Thus a rapid rise of the strata is indicated northward from the Wurtemburg bridge, and also from the mouth of Squaw Run, for near there, at No. 70, the Vanport limestone on the Mehard farm has an elevation of 1020, and the Middle Kittanning coal 1085. The Vanport here measures 20 feet and is overlain by 15 feet or more of brown shale. The stone was formerly burned for lime and much is still available for that purpose or flux or cement manufacture. Near here, at No. 99, the Lower Mercer limestone occurs at the bridge with an elevation 40 feet higher than at No. 67, or 920 feet above sea level. Above the limestone 30 feet, a gray siliceous fire clay underlies a 7-foot cliff of Homewood sandstone. The Brookville coal blossom occurs above it with an elevation of 980 feet and is underlain by 5 feet of gray plastic fire clay which is reported to be of excellent quality. Down stream the creek falls over 40 feet of massive Upper Connoquenessing sandstone. Northward at Nos. 98 and 101 the white blossom of the Homewood clay is conspicuous at elevation 955 feet.

The hill road east of Squaw Run presents section 19 (pl. VII). The Upper Freeport limestone occurs 30 feet deep in a well near No. 103, and an old opening on the Middle Kittanning coal lies in the valley 125 feet lower or at an elevation of 1135.

Along Squaw Run, the Vanport limestone outcrops 15 feet thick at Nos. 104 and 109, at elevation 1070 and 1075, and it occurs at an altitude of 1130 in the Van Gorder well at No. 128. The Middle Kittanning coal has an elevation of 1155 feet on Wm. Price's farm No. 107 and is 30 inches thick (Fig. 13, 17): northeastward its elevation is 1150 at No. 110 and 1175 at No. 111.

Along the ridge road between Squaw Run and Duck Run the Middle Kittanning at No. 105 is 1145 feet above sea level and 28 inches thick (Fig. 13, 16). The Lower Freeport coal blossom rises northward from 1215 above No. 107 to 1220 at No. 108, 1255 at No. 112 and 1295 at No. 129, where it lies 30 feet below the road corner.

Valley of Duck Run.

Along Duck Run, about half a mile above its junction with Squaw Run, at No. 97, the Homewood coal and clay occurs 10 feet below the road forks or 955 feet above sea level. The outcrop is seen along the road beneath the Homewood sandstone. It rises to an elevation of 990 feet at No. 106. The Vanport limestone was once extensively quarried along the run by Mr. Johnson and rises in elevation from 1045 feet at No. 97 to 1095 feet at No. 113, 1120 at No. 127, and goes under drainage at Mr. Houk's No. 130, 1140 feet above sea level. The Lower and Middle Kittanning horizons lie 35 and 75 feet above the limestone on both sides of the run. Near its head several old banks occur on the Middle Kittanning coal. At A. T. Newton's, No. 131, this coal is 70 feet above the limestone and

40 feet above the Lower Kittanning, which was struck 18 inches thick in a well. Northward at No. 132 the Middle Kittanning coal blossom occurs under 25 feet of brown shale, and farther north, drift conceals the rock outcrops.

Area Between Duck Run and Spangler Run.

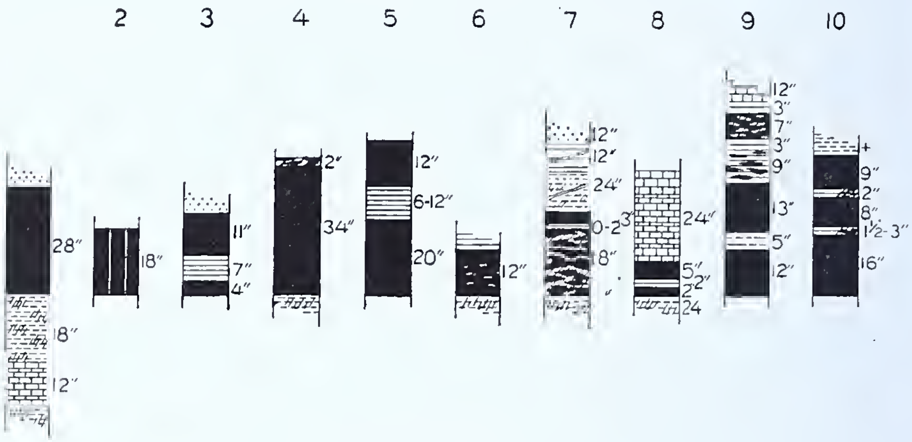
The southern margin of this area is occupied by Pottsville sandstones. The Homewood and Mercer horizons are concealed beneath terrace silts, but the Upper Connoquenessing sandstone is exposed along the creek, dipping westward. It may be seen at No. 71, 890 feet above sea level; and is 20 feet thick at the quarry at No. 72. Westward it was worked for curbing early in the century at the Moody and Buck quarries, Nos. 73 and 74, where it measures about 35 feet and reaches to 885 feet altitude. At Rock Point the massive portion is 50 feet thick and is underlain by 20 feet of sandy shale extending down to railroad level. Along Beaver River at Mr. Ingham's quarry, No. 75, a 30-foot face was quarried for bridge stone and curbing. The top has an elevation of 840 feet. Northward the Homewood sandstone is exposed 35 feet thick at quarries of the Consolidated Stone and Mining Co., Nos. 77 and 78, where its top is 925 feet above sea level. Northward at No. 86 an old quarry exposes 20 feet of the Homewood sandstone, and nearby, at No. 87 the Upper Connoquenessing is 65 feet thick and reaches to 845 feet above sea level.

Above the Pottsville formation, west of Duck Run, occur outcrops of the Lower Freeport and Middle Kittanning coals and of the Vanport limestone. At M. M. Newton's bank, No. 96, the Middle Kittanning is 36 inches thick (Fig. 13, 15), and has an elevation of 1110 feet. The Lower Kittanning blossom in the road is 40 feet lower. Westward at Nos. 95 and 93 similar relations exists. Northward from this place the beds rise, the Middle Kittanning having an elevation of 1135 feet at No. 94 and 1170 feet at No. 114. The Lower Freeport elevation is 1205 at No. 92 and 1235 at No. 114. Southward the same bed lies 1160 feet above sea level at No. 82 near Ellwood City, and 60 feet above an old opening on the Middle Kittanning. In this vicinity section 20 (pl. VII) shows about 20 feet of Vanport limestone and the associated strata.

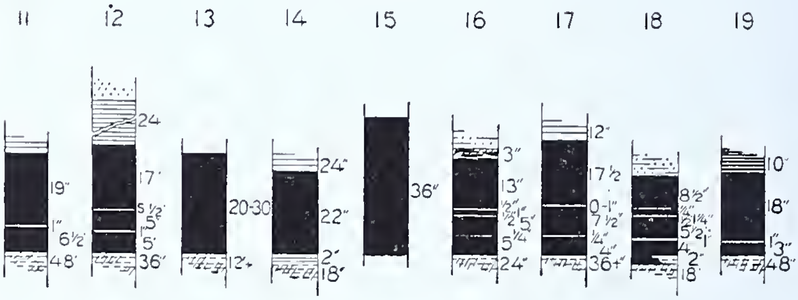
Northwest of Ellwood City, the Vanport is exposed for 10 feet at No. 81 and lies 1000 feet above sea level and 80 feet lower than the Middle Kittanning coal to the west. The latter bed occurs about 10 feet higher at the Wallace bank, No. 83, where it measures 26½ inches and is underlain by 4 feet or more of fire clay (Fig. 13, 11). The Lower Kittanning coal lies 40 feet lower in the road, and to the west, along Lone Dell Run, has the same altitude at No. 84.

Sixty feet lower, at No. 80, the top of the Vanport appears in the creek, or 980 feet above sea level. Nearby at No. 76 the same bed is 10 feet lower. Near the mouth of the creek, section 21 (pl. VII) is exposed. Northward at the quarry of the Consolidated Stone and Mining Co., No. 79, the Vanport limestone is 18 to 20 feet thick along an exposed face 200 yards long. From an elevation of 980 feet at the north end it dips about 6 feet to the southeast. Northward on the property of the Chewton Coal Company the same bed

Coal Beds other than Middle Kittanning



Middle Kittanning



Middle Kittanning (Cont.)

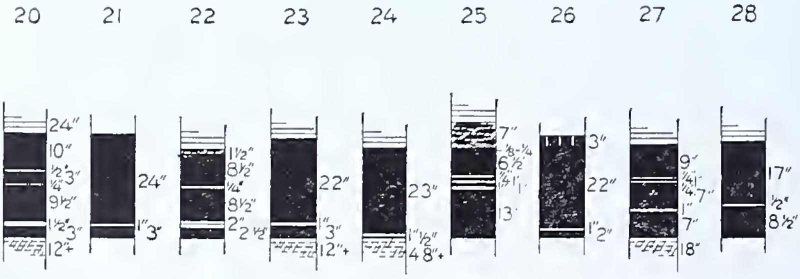


FIGURE 13. Coal sections in northeastern district.

lies 1000 feet above sea level and is exposed for 10 feet. Sixty-five feet above it at No. 85 the Middle Kittanning coal is 29 inches thick (Fig. 13, 12). Section 22 (pl. VII) occurs at this place.

Valley of Spangler Run.

East of Spangler Run and north of the locality last mentioned the Mercer iron ore was once mined at No. 88. Above it in the road the Homewood sandstone is 35 feet or more thick. The Middle Kittanning coal at Mr. Ford's bank, No. 89, is reported to average 26 inches thick and to overlie 12 feet of fire clay (Fig. 13, 13). It dips gently to the south. Fifty feet below it the Lower Kittanning coal is said to be an 18-inch bed of cannel coal (Fig. 13, 2), and 15 feet lower, or 1035 feet above sea level, the top of the Vanport limestone outcrops. It has the same level in the road at No. 90. Eastward at Mr. Wolf's bank, No. 91, the Middle Kittanning coal has a thickness of 22 inches (Fig. 13, 14) at elevation 1115 feet.

Along Spangler Run the Vanport limestone is partially exposed. It rises from an elevation of 1040 feet at No. 117 to 1060 feet at No. 118, 1090 at No. 116, and 1115 on the Fallis farm, No. 134. The "Buhrstone" iron ore was formerly mined from the shales above the limestone. A coal blossom at No. 119 represents the Brookville or Clarion horizon. The Lower Kittanning outcrops at No. 115 at an elevation of 1105 feet, or 15 feet higher than the Vanport limestone at No. 116, thus indicating a dip towards the latter place.

Northward at No. 125 the Clarion coal blossom appears 40 feet below the Vanport limestone. To the west, at No. 124, the Middle Kittanning is 1170 feet above sea level, and at No. 134 it is 10 feet higher and 65 feet above the limestone outcropping here and nearby at No. 135. The coal rises to 1200 feet at No. 133 where the Lower Kittanning blossoms 25 feet lower.

Eastward at No. 126 the Middle Kittanning coal has a thickness of 23 inches in the Jones bank at elevation 1180 feet (Fig. 13, 18).

Valley of Snake Run.

Along its lower course Snake Run cuts through the gravel terrace on which Chewton is situated. Northward, at No. 120, boulders indicate the approximate top of the Homewood sandstone at elevation 925 feet. The top of the Vanport limestone is 110 feet higher at the crusher of the Lawrence Limestone Company's No. 1 quarry, but dips 15 feet southeast in a quarter of a mile. The Middle Kittanning coal occurs 60 feet above the limestone at No. 121. The limestone is 16 to 20 feet thick, but only the top 12 feet is removed.

The stripping includes 5 to 10 feet of shale and the same thickness of drift. Beneath the limestone the Scrubgrass coal is exposed 6 inches thick, and the underlying brown shale 10 feet. To the west coal blossoms in the road at No. 123 lie 980 feet above sea level and probably represent the Clarion horizon. At quarry No. 2 of the Lawrence Limestone Company at No. 122, the stone is 20 feet thick and is underlain by 1 foot of coal and overlain by 2 feet of shale and 10 feet of drift. Its elevation is 995 feet, and that of the Middle Kittanning coal above it is 1060. The Lower Kittanning is reported to lie in the middle of this interval. Northward at No. 138, the elevation of the limestone has risen to 1040 feet; the Lower Kittanning coal is 40 feet above it, and the Middle Kittanning coal 30 feet higher at several old openings. Section 23 (pl. VII) occurs at this place. As the beds rise rapidly to the northeast the Middle Kittanning is 1165 feet above sea level at No. 137, and the Vanport limestone 1085 feet. Northeastward at John S. Hanna's bank, No. 136, the same coal is 1180 feet above sea level and measures 22 inches (Fig. 13, 19). From here the coal dips to the northwest and at Mayberry's bank, No. 152, has an elevation of 1160 feet and a thickness of 24½ inches (Fig. 13, 24). The Vanport goes under creek level at this place.

At the head of Snake Run, a coal bank, No. 153, on the same seam has an elevation of 1170 feet, while to the north at No. 154, the limestone is 15 feet thick in the falls and lies 1095 feet above sea level.

Area west of Snake Run.

In the area west of Snake Run and south of McKee Run the most prominent outcrops are those of the Vanport limestone and the Middle Kittanning coal, although Pottsville sandstone and coal are also exposed.

At No. 143 is the opening of the Rock Point Coal Company on the Middle Kittanning bed. The workings extend under this hill and the area to the north. At No. 141 the coal is 28 inches thick (Fig. 13, 21) and lies 1090 feet above sea level. It rises to 1115 feet in the monkey drift to the east, No. 140, where the coal has similar thickness (Fig. 13, 20). Near an abandoned drift, No. 139, the Lower Kittanning has been opened just above water level.

East of Irish Ripple at No. 144, 10 feet of the Upper Connoquenessing sandstone is exposed above the railroad and the top of the hill is capped by a cliff of the Vanport limestone which was stripped and quarried by the Interstate Limestone Company, of Youngstown, Ohio.

This bed was formerly quarried at No. 142 where it is exposed 10 feet or more thick and lies 1025 feet above the sea. Northwestward at No. 145 the Upper Connoquenessing sandstone is exposed 40 feet thick in an old quarry. Below it in the creek to the east the Quakertown coal is exposed 22 inches thick but broken by a 7-inch parting (Fig. 13, 3).

South of East Moravia a hummocky glacial deposit lies east of the railroad. In the ravine at No. 146, a 5-inch coal is exposed at or near the Mercer horizon. The hill to the north contains a considerable area of the Middle Kittanning coal and Vanport limestone. The latter bed is used for road metal at West Pittsburg. South of Union Valley, at No. 147, it is exposed 10 feet thick along the west side of the hollow at elevation 1055 feet. Eastward it rises to 1070 at No. 148 and is 20 feet thick. The Middle Kittanning coal in a bank 85 feet above it, measures 23½ inches (Fig. 13, 22). A local rise to the northeast makes its elevation 1170 feet at Shoff's bank, No. 151, where the coal is 26 inches thick (Fig. 13, 23). Near Union Valley at No. 150, an old opening at an elevation of 950 feet was probably on the Homewood coal, or one of the Mercer seams.

Northern Area.

North of Energy and east of Joyce the surface is deeply covered by glacial drift and few outcrops occur. Near the east margin of the map at No. 156, the Middle Kittanning coal has an elevation of 1240 feet and a thickness of 30 inches, but is very impure (Fig. 13, 25). At No. 155, nearby, a fire clay blossom at an elevation 65 feet higher probably lies at the Lower Freeport horizon. In a well to the northwest, No. 157, a coal reported 35 feet below the surface or 1265 feet above sea level probably is at or near the Middle Kittaning horizon, as is also the coal blossom to the northwest at No. 172, which has an altitude of 1175 feet.* In this area lay the Big Meadows gas field described on page 204; the well records, which are imperfect, indicate an altitude for the Vanport limestone, rising from 1140 feet around Energy to 1190 feet near the map margin at No. 173. Northward the Middle Kittanning coal is 25 inches thick at No. 174 (Fig. 13, 27) and 26 inches in the Nelson bank, No. 176 (Fig. 13, 28). Its elevation is 1240 feet. The hilltop is underlain by a thin coal about 65 feet higher, No. 175, probably representing the Lower Freeport. Northwestward at No. 177, a 20-foot sandstone quarried for local use is perhaps the Homewood. Westward at No. 178 a railroad cut reveals a 12-foot sandstone underlain by 23 inches of impure coal (Fig. 13, 7), the elevation of which is 1045 feet. This coal has the relations of the Homewood and may be that bed, but according to an earlier survey is nearly 100 feet higher than its calculated position at Joyce, as described later.

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*Editor's note: This observation radically disagrees with the structure of the Middle Kittanning coal as interpreted by Dr. DeWolf, and with other observations made nearby by him. Sufficient data for unquestionable mapping are lacking, and, owing to the masking of outcrops by glacial material in this portion of the quadrangle, are difficult to obtain. Although obviously in disagreement these statements and the maps are published as received from Dr. DeWolf.

North of McKee Run and west of Joyce the area east of the Beaver-Shenango Valley has many imperfect exposures of Pottsville and Allegheny horizons.

Near West Pittsburgh a quarry at No. 149 exposes a 20-foot sandstone which is probably the Lower Connoquenessing bed. East of Union Valley the Vanport limestone lies about 100 feet above the creek or about 1070 feet above sea level. At No. 158, it is 20 feet thick in a waterfall. Above it 75 feet the Middle Kittanning coal was formerly opened along the road and westward.

Along "Hog Hollow" north of Union Valley the Brookville, or possibly the Homewood, coal was once worked at No. 159, 985 feet above sea level. Above it 75 to 80 feet the Vanport limestone ledge is exposed on both sides of the valley. At No. 160 the Middle Kittaning lies 80 feet higher and at No. 162 the same relation appears. Here, descending from Schweikert's coal bank, section 24 (Pl. VII) was measured. The Lower Freeport coal in the hilltop, No. 163, is reported to be 28 inches thick (Fig. 13, 1) and to have a sandstone roof and an underlying limestone. The coal lies 1250 feet above sea level and 100 feet above the mining operations on the Middle Kittaning seam, No. 162 (Fig. 13, 26), and 75 feet above the old banks at the road corner, No. 168. In section 24, the Brookville (?) coal is reported broken by a thick parting (Fig. 13, 5), while the Homewood or "Four-foot" is also said to be impure. Only the blossom of the Mercer or "Blue limestone" coal was seen and this is at the level of the new railroad, No. 161, and is underlain by the massive Upper Connoquenessing sandstone. Northward a coal blossom at No. 170 is probably the Lower Mercer or Homewood seam. The Vanport limestone at Mr. Lutton's, No. 171, is 10 or more feet thick and is crushed for road metal. Its elevation 1105 feet is about the same as at No. 169, one mile westward.

Along the river bluff from West Pittsburgh to the mouth of Big Run road cuts and ravines offer partial exposures which are difficult of correlation.

A coal blossom at No. 164 at an elevation of 975 feet, is probably one of the Mercer beds. Northward at No. 165 an old clay pit exposes 20 feet of brown nodular shale, and beneath it 5 feet of gray fire clay, which lies 40 feet above the road, or 895 feet above sea level. This horizon is probably the same as the 8-inch coal 10 feet above the road corner at No. 184, at elevation 890 feet, and therefore lies 50 feet or more below the Lower Mercer horizon and represents the Quakertown seam. The hard white sandstone exposed 10 to 30 feet thick in the quarry at No. 167 and the road to the south is probably the Lower Connoquenessing bed and coal blossom 20 feet above it, or 870 feet above sea level at No. 166 is therefore at or near the Quakertown horizon, and another blossom 75 feet higher is probably the Upper Mercer. Such interpretation of the stratigraphy implies a northwest dip of 25 feet from No. 165 to No. 166 and thence a rise of 20 feet to No. 184.

The ravine sections 25 and 26 (pl. VII) show interesting variations in the Pottsville measures and a sudden thinning of the Vanport limestone from 12 or more feet to one foot within half a mile. The limestone was formerly extensively quarried at No. 183 by the Marquis Limestone Company. To the southward considerable stone still remains. The quarries here are at elevation 1105 feet. The thin limestone at the top of section 25 (Pl. VII) is 45 feet lower. Northward at No. 182 a coal blossom at or near the Quakertown horizon is at elevation 915 feet. Nearby at No. 181 the Lower Mercer coal is 52 inches thick but very impure (Fig. 13, 9). It lies 990 feet above sea level and 10 feet above the Upper Connoquenessing sandstone, which is quarried here in a 15-foot face. The Upper Mercer coal shows in the road about 25 feet above the lower seam and the Homewood sandstone in a 5-foot ledge 20 feet higher at the bend in the road. West of Rigby at No. 185 a cut exposes 40 feet of interbedded sand and gravel with some boulders. Northward at No. 180 a 15 foot bed of sand and gravel is worked and nearby at No. 179 another pit shows 60 feet of the same materials.

Eastward, section 27 (pl. VII) presents a series of Pottsville beds whose identity is not clear. The top sandstone is probably the Upper Connoquenessing, though possibly the Homewood. Section 28, at the cascades near Joyce, is obtained from a former survey[1], and only the top sandstone is now exposed. This seems to be the Upper Connoquenessing bed, in which case the reported Mercer horizon below it is the Quakertown instead, and the Homewood sandstone occurs eastward at No. 178.

North of Big Run the Vanport limestone has an elevation of 1115 feet at the quarry of the Lehigh Portland Cement Company, No. 190. Here the following section was measured:

Section at Lehigh Portland Cement Co. quarry, No. 190.

	Ft.	in.
Shale	15	
Limestone	15	
Shale, black	1	
Coal	1	2
Fire clay	8	
Shale	1	

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[1] Pennsylvania Second Geol. Survey, Rept. QQ, p. 148.

Further east and 15 feet lower at the new quarry of the same company, No. 191, the limestone is overlain by shale and underlain by coal and the following layers are distinguished:

Section of Vanport limestone east of New Castle, at No. 191.

	Ft.	in.
Shale	10	
Limestone	15	5
(names of beds)		
Top	3	8
Bull	1	10
Thirty-inch	2	3
Hard	1	2
Soft	1	2
Ten-inch		10
Bottom	2	
Poor stone	2	6
Coal	1	

In the city of New Castle drift conceals the rocks almost entirely. The Upper Connoquenessing sandstone occurs, however, 18 feet thick at No. 192 and 3 feet thick at No. 189, the elevations being about 960 and 970 feet.

In the triangular area between Mahoning and Shenango rivers and the northern boundary of the quadrangle exposures are scarce. Section 29 (pl. VII) indicates the stratigraphy and agrees in general with sections 25 and 26 near Rigby. The Upper Mercer coal is 9 inches thick (Fig. 13, 8), and the Brookville (?) 12 inches (Fig. 13, 6). A 2-inch coal between them is underlain by sandy fire clay and probably is the Homewood horizon. The Vanport limestone, which is 1060 feet above sea level, is 12 inches thick and shows "cone-in-cone" structure. A short distance north of the section it measures 5 or more feet. The Lower Connoquenessing sandstone is 20 feet thick at an old quarry near the box factory, No. 187. Westward a coal at No. 188, at 1000 feet above sea level is 37 inches thick and is regarded doubtfully as the Lower Mercer (Fig. 13, 10). This is possibly the same as the coal formerly opened at No. 194 where its elevation is 1030 feet, but at No. 194 it has 10 feet of sandstone above, and a sandy fire clay beneath and thus resembles the Homewood. The Homewood coal probably was prospected at No. 193, at an altitude of 1060 feet, and also westward at Nos. 195 and 196, 5 and 10 feet higher. Section 30 (pl. VII), exposed nearby, shows the same coal still higher by 20 feet and overlying the siliceous fire clay, characteristic of the Homewood horizon. At an old roadside quarry at the base of the section the Upper Connoquenessing sandstone is 15 feet thick, and boulders in the road indicate an additional 30 feet below it. Northward along the West New Castle road one of the Kittanning coals, presumably the lower, is mined by a slope at an elevation of 1135 feet on the Matthew's farm, No. 197, where it is reported to be 34 inches thick (Fig. 13, 4) and to overlie 10 feet of fire clay. Probably the same coal was reached by the old slope one-fourth mile southeast along the north-south road.

ECONOMIC SUMMARY.

The northeast district contains deposits of coal, clay, shale, limestone, building stone, sand and gravel. Of these limestone is perhaps of leading importance, though all contribute to the region's wealth.

Coal.

Coal occurs at 11 horizons in this district but only one, the Middle Kittanning, has yielded much coal of value. The other beds which have been utilized for local use are the Homewood and Lower Freeport north of Union Valley and the Homewood and Lower Mercer in the vicinity of New Castle and Mahoningtown. Sections of the various coals are presented on Figure 13.

The Middle Kittanning coal has been extensively worked in the past and is still mined by the Rock Point Coal Company near Chewton and the many local banks which have been enumerated. Analyses of the bed are given on page 165.

The accompanying sections (Fig. 13) indicate thicknesses of 22 to 36 inches. The roof is shale and the floor a fire clay reported variously from 1 to 4 feet thick and 12 feet in one bank east of Chewton, No. 89.

Thin bands of clay or shale are conspicuous. One occurring from 2 to 8½ inches above the floor and measuring from ½ to 2 inches is widely persistent through the area. Another from 5 to 8 inches higher is shown in some sections, and commonly occurs double, with an inch or more of coal between. Although these impurities detract from the value of the bed, they can be readily removed in mining and leave the coal of unusually high grade.

The coal has been removed from a considerable acreage but most of the mining has been along the outcrop for local use, so that many hundreds of acres remain for testing and development where railroad sidings are warranted either for the coal alone or for this and other mineral resources combined.

Fire clay.

There is no present production of fire clay but several horizons show clays of promise. Among the more important are the Lower Kittanning, Homewood and Brookville (?).

The Lower Kittanning clay horizon has not been tested, but is present from 30 to 40 feet below the Middle Kittanning, as shown on the map. The clay appears to be accessible from New Castle Junction southward. On account of its great value elsewhere in the quadrangle its examination here is desirable.

The Homewood clay is a hard siliceous bed of light-gray color. Its resemblance to high grade non-plastic fire clays elsewhere in the coal fields seems to warrant its careful examination. It is especially prominent along the lower course of Duck Run, west of Rigby and north of Mahoningtown, and its horizon occurs along the Shenango and Neshannock above New Castle.

The Brookville (?) clay has been opened on the Mehard farm, No. 99, east of Ellwood City. It is a gray plastic bed about 5 feet thick and is said to be highly refractory. The same horizon is elsewhere exposed along Duck Run, west of Rigby and north of Mahoningtown.

Shale.

Shale suitable for building and paving brick and cement manufacture occurs commonly in this district and warrants further development along the railroad lines. The best known bed is that which overlies the Vanport limestone and is worked here and elsewhere in the quadrangle for brick and cement manufacture. Other horizons of promise are those over and below the Middle Kittanning coal, and near the Mercer coals.

The light-brown shale above the Vanport is utilized by the Lehigh Portland Cement Co. in connection with the limestone for making cement, and alone or with the Scrubgrass underclay for building and paving brick. Further details of manufacture are given on a later page.

A shale and fire clay (?) occurring at or near the horizon of the Quakertown coal was formerly made into brick at No. 165 south of New Castle Junction. Judging from the old stock pile the bricks were rather soft and inferior to those now made from the Vanport horizon.

Limestone.

Limestone occurs at the Upper and Lower Freeport, Vanport, and Upper and Lower Mercer horizons, but of these all are worthless except the Vanport, and it has in the past been the most valuable resource of the district.

The Vanport limestone commonly has a thickness of 12 to 20 feet, but is thin and worthless locally in the ravine near New Castle Junction and above Mahoningtown (Secs. 25 and 29, pl. VII). Where thick, its main portion is suited for flux and for manufacture of cement, but the lower bed is good only for ballast or concrete. The extensive outcrop of the bed, as indicated on the map, shows many localities favorable for new operations.

The commercial exploitation of the bed has been chiefly for flux and lime in the past, but recently its use for cement manufacture has become prominent. It was formerly shipped extensively from quarries along Duck Run, east of Irish Ripple and west of Rigby, and is still quarried near Chewton by the Consolidated Stone and Mining Company, No. 79, and the Lawrence Limestone Company, Nos. 121 and 122. Northward the Lehigh Portland Cement Company has extensive quarries at Nos. 190 and 191, and the Shenango Limestone Company was opening up a large property south of Rigby in 1906 but this operation had been adandoned in 1926. Further notes regarding quarrying and utilization of this bed are given on later pages.

Sandstone.

The Pottsville formation offers three horizons of massive sandstone suitable for heavy construction work or curbing. These have been extensively quarried between Chewton and Ellwood City and on a similar scale at scattering localities to the north, as shown by the later table of quarries.

The Homewood sandstone in the region south of Chewton is a hard coarse-grained rock about 40 feet thick. The top portion is slightly cross-bedded and locally contains quartz pebbles as large as a pea. The lower stone is massive and nearly free from bedding planes. Throughout, the color is light-gray to light-yellow.

The Upper Connoquenessing sandstone is a hard, fine-grained, light-grey or white rock of suitable character for heavy structural purposes. The total exposed thickness is 65 feet, though the average is about 35 or 40 feet. Of this the top 10 feet is commonly cross-or thin-bedded, while the remaining massive portion yields blocks of large size.

The Lower Connoquenessing sandstone is exposed 20 feet thick in quarry faces and is fine-grained, hard and white in color. It has not been worked on a large scale.

The following table summarizes the data obtained from quarries of the northeast district. Further notes on quarry methods are given on a later page.

Sandstone quarries of Northeast District.

Map No.	Name of operator.	Character of shipments.	Name of bed.	Exposed thickness Feet.
		Curbing.	Upper Connoquenessing	20
73	Moody.	Curbing.	Upper Connoquenessing	35
74	Buck	Curbing.	Upper Connoquenessing	35
75	Ingham	Dimension stone and curbing.	Upper Connoquenessing	30
77	Consolidated Stone and Mining Company	Dimension stone and curbing.	Homewood	35
78	Consolidated Stone and Mining Company	Dimension stone and curbing.	Homewood	35
86			Homewood	20
87		Dimension stone	Upper Connoquenessing	65
145		Dimension stone (?)	Upper Connoquenessing	40
149		Local use	Lower Connoquenessing	20
167		Local use	Lower Connoquenessing	10
181		Local use	Upper Connoquenessing	15
177		Local use	Homewood (?)	20
187		Local use	Lower Connoquenessing	20
196		Local use	Upper Connoquenessing	15

TECHNOLOGY.

Introduction.

In connection with the investigation of the geology of the area observations were made of the methods employed in mining or quarrying the mineral deposits. Most of the operations are conducted by methods which are in common use throughout regions where similar mining conditions exist. These require little comment. On the other hand, within this area coal is being won by steam shovels, and limestone is being mined by underground methods. Although these methods are used elsewhere they are sufficiently uncommon to deserve more than passing mention.

Many of the deposits are in the class denoted by economists as "marginal." During active marketing conditions, when prices are high, such deposits are actively worked. When the urgent demand decreases and prices decline, operations are suspended. These phases are well illustrated each year by some of the coal mines, the peak demand occurring in the fall and early winter. Again, during periods of labor difficulties in coal mines elsewhere (e. g., a strike in the anthracite regions) excellent temporary market conditions prevail.

Another economic law is illustrated by the competition between the cement and the stone industries. For many years the quarries along Beaver River furnished building stone, curbing and other stone products to communities within a large radius. Some of the office buildings in Pittsburgh, for example, are reported to have been built with stone from this locality. The very great expansion of the cement industry within the past decade, however, has been accomplished somewhat by invading the markets of other industries. As a consequence, demand for stonework has declined, resulting, in turn, in suspension of operations in the quarries of all but the most strongly entrenched operators.

Conditions such as these may seriously affect the production, costs, and recoveries obtained by workings on the mineral deposits. Individual operations are thus individual problems, and therefore care must be used in interpreting the following generalizations.

COAL.

Coal mines. Although the mine openings in this district are numerous only about a dozen mining companies regularly mine and ship coal. The greater number of openings are those which represent either abandoned workings or sources of supply only during peak seasonal periods. The beds worked are the Middle Kittanning, Upper Freeport, and East Palestine. The operations on the Lower Kittanning bed are in conjunction with the recovery of the underlying clay, and although some of these operations are independent, most of them are more or less connected with the local brick companies.

Some of the mines have been productive for many years, and hence the working faces are at considerable distances from the mouth. At the Crescent mine of the Crescent Portland Cement Company, for example, the present workings are 1½ miles from the mouth of the haulageway.

The markets are in Beaver Falls, New Castle, Youngstown, Sharon, and other places as distant as Cleveland. Some of the coal has been purchased for locomotive use by the railroads; some of it goes to local manufacturing concerns; much of it is used in domestic furnaces, churches, and schools. Motor truck haulage from mine tipple to point of consumption minimizes handling, thus favoring the use of locally mined coal.

General mining conditions. Under the headings Stratigraphy and Structure it has been shown that the coal beds outcrop in the valleys and along the hillsides; and that the beds are not truly horizontal, but occupy warped planes. Furthermore, inasmuch as the beds occur in a sequence, vertically, their depth below the surface ranges between outcrop conditions and a hundred or more feet. The beds which occur exceptionally near the surface with sufficient area (which is very closely proportional to tonnage) may be recovered most expeditiously by removing the surface covering, then removing the coal. Such operation, called "stripping," is practised in the western portion of the New Castle quadrangle. For the beds otherwise situated, other methods of recovery are practiced.

Where the beds are under cover which is 40, 50 or more feet deep, or where the surface is particularly valuable, it is more economical to mine the beds by underground methods, using either shafts or drifts to gain access to the coal. Each of these methods has its advantages, too well known to require comment here. Within the New Castle quadrangle there are very few deposits worked by shafts. On the other hand there are several hundred drifts which are now, or have been, worked.

Mining methods. The underground mines (as contrasted to the stripping operations) are almost invariably opened by drifts, single or double entry, and are worked by the room-and-pillar method. Rooms, pillars, and entries are given dimensions suitable to the local roof and floor conditions, the rooms being usually 7 - 11 yards wide and 40 - 75 yards long. Main entries are driven 6 - 9 feet wide, and cross entries are usually 6 - 7 feet wide. The dimensions of these elements vary somewhat with the size and importance of the undertaking. Mining is done by pick, with some shooting. The average production rate is about 3 tons per man-day.

In the vicinity of Darlington the Lower Kittanning coals and underlying fire clay are mined from the same workings, although not from the same rooms simultaneously. The roof over this coal bed is sufficiently coherent to permit mining the coal, but it falls shortly after the coal is removed. As a consequence of this condition the clay is first removed, leaving the coal to protect the roof. Subsequently the coal may be recovered to be used as fuel in the local brick plants. The latter step is not always followed, however, for it is the practice at some mines to abandon the working places after removal of the clay.

The coal beds in the upper parts of the hills have much less cover than the lower beds. This situation is advantageous in that it permits smaller pillars and wider rooms, thus increasing the tonnage obtained by first mining. On the other hand, such practice occasionally permits the roof to creep, crushing the coal and timbers and making impossible the recovery of pillars. Creeping and heaving are particularly destructive during the periods of idleness.

Roof conditions. Above the Upper Freeport the roof commonly is slate 1 - 5 feet thick, over which is a massive, coarse sandstone. As usually found, a draw slate, 4 - 12 inches thick, overlies the coal, although locally there may be no slate between the coal and the sandstone. The roof of the Upper Kittanning is a hard coherent shale suitable for economic mining of the coal. Rolls are not uncommon. Over the Middle Kittanning the roof is hard, coherent slate, excellent from a mining standpoint. Locally it is so coherent that it is difficult to break, remaining firm without props over an area of 8 to 10 rooms. The roof of the Lower Kittanning is a shale sufficiently hard to permit mining although it comes down soon after the coal is removed. Because of this characteristic, in local practice the coal is taken out only just prior to the abandonment of the workings. The Brookville coal is beneath a roof of shale which offers no particularly great mining difficulties. For other reasons, however, the Brookville and lower coals are not extensively worked in this area.

Floor conditions. The Upper Freeport is underlain by fire clay 1 - 3 feet thick which is over a hard limestone 3 - 4 feet thick. Locally, squeezes are common in this bed. The floor of the Upper Kittanning is soft shale which locally may be troublesome because of its insecurity. Rolls in this floor are sometimes present. Beneath the Middle Kittanning coal soft fire clay occurs. Although this is sometimes troublesome it does not prevent mining operations. The floor of the Lower Kittanning is commonly the soft gray fire clay, 2 - 3 feet thick, which is underlain by the harder blue fire clay. Both the clay and the coal are mined. The Brookville coal may have either shale or fire clay for floor.

Haulage. The various methods of haulage used in the mines in this area are determined by the local conditions and by the size of the undertaking. At Glenkirk the Crescent mine of the Crescent Portland Cement Co., is electrified throughout, hence electric haulage is used. Other mines use endless or tail rope haulage (mules for gathering), mule haulage, or even man-power (in some of the smaller operations). The State Line Coal Co. mine had a main rope 20,000 feet long. This was said to be one of the early installations of this type in the United States. Wooden cars are used. With animal haulage the capacity of the cars is 1 - 1½ tons. With mechanical haulage the capacity of the cars is 1½ - 2½ tons.

Ventilation. As with other features the ventilation equipment varies considerably. Fire damp is absent, but some black damp is found near old workings. At the mines where steam power is used for other purposes ventilating fans 6-12 feet in diameter are steam-driven. At the State Line mine, a fan was driven by a gas engine. Many of the mines do not come under the State mine inspection code, hence a variety of ventilation makeshifts can be found. A shaft and fire basket may be used, or ventilation may be entirely neglected.

Drainage. One of the great advantages of mining by drifting is that of natural drainage of the workings. Even under the most adverse condition—with the workings down the dip—the height through which it is necessary to raise the mine water is always much less than would be the case were vertical shafts employed. Inasmuch as there are but few shafts in this area the mine-water problems are minimized; and at the places where shafts are used the amount of water handled is very small. The power for actuating the pumps is customarily steam, although some electric-driven pumps are used. In isolated working-faces and in some of the smaller mines hand pumping is sufficient to take care of all inseeping water. On occasion, siphons have been used.

Surface arrangements. In this district, as elsewhere, the elaborateness of the surface plants bears some relation to the size of the mining operation. One plant has a hollow tile power house; the larger mines have permanent buildings. The smaller mines have wooden frame structures, some of them so rudely constructed that they are barely shields against the weather.

Tipples are commonly of the cross-over type. Some of the coal is marketed as run-of-mine, but much of it is passed over 3/4-inch or 1-inch screens (punched plate) thus making two products. Both the

Upper Freeport and Middle Kittanning coals break about equally in the current mining practice, and about one-quarter to one-third of the coal mined passes through $\frac{3}{4}$-inch openings. Bins may or may not be part of the equipment.

The loading facilities will vary somewhat depending upon whether the coal is shipped by railroad or motor truck. In some instances the coal is dumped from the mine cars into the motor trucks; in others, bins and chutes are used; still other operations have more or less elaborate equipment for loading freight cars for railroad transportation.

COAL STRIPPING OPERATIONS.

Within the area discussed in this report are two coal-stripping operations. At these places the coal which is recovered occurs as an approximately horizontal bed beneath 10, 20, 30 or more feet of overburden. The operations consist of (1) removing the overburden and (2) loading and removing the coal. Steam shovels are used for handling the materials; the operations are similar to other operations where loose earth is handled in large quantities. Care is necessary, however, in order not to include any of the coal in the overburden; and to remove all of the coal (but only the coal) for shipment. For the stripping operations long-boom shovels are required; for coal removal the ordinary short-boom loading shovel is used. Ordinarily the top surface of the coal bed is better as a roadway and as a working surface than the underlying (usually) clay. The coal surface drains more easily and is not greatly affected by either the weather or traffic during the short time it is exposed; on the other hand underclays may be considerably affected by these conditions, and production may be seriously hampered.

In an operation of this kind interest charges on the equipment and labor charges, both large, are functions of time. It is therefore essential that the output be kept at or near the maximum, as otherwise the true costs may be excessive. The management of an operation of this character depends for its success upon the careful balancing of stripping and coal removal operations with haulage.

Methods.

Applicability. In order that stripping methods be profitably used it is essential that the coal bed be near the surface, and preferably flat-lying, and of uniform thickness and characteristics. Obviously, the larger the area available the more stable will be the operation. The cost of moving the overburden will vary with the thickness of overburden; coal beneath thin overburden is therefore more advantageously situated than the same coal beneath thick overburden. It is also obvious that returns will be greater the thicker the coal. Experience has indicated that the minimum profitable ratio between thickness of coal and thickness of overburden is about 1 to 12; inasmuch as this is the ratio of feet and inches it therefore happens that the number of inches of coal, expressed as feet, will represent the approximate limit of thickness of overburden which can profitably be removed.

As pointed out later there is but one possible use for the surface after stripping operations are completed. Inasmuch as even in remote localities the land is usually of at least some agricultural value before operations are undertaken, this cost must be entirely written off by the coal extracted. At present there is no salvage value to property after the extraction of the coal. Furthermore, the coal would be almost valueless unless transportation facilities were nearby; and in regions which have adequate transportation systems the land values are by no means nominal. This charge is therefore a serious one.

Equipment. Excepting transportation facilities only excavating machinery is needed. Transportation may be had in numerous variations suitable for local conditions, ranging from motor trucks to standard guage railway. Excavating machinery may embrace a similar latitude of types, but power-driven shovels have become standard.

The shovels are required to do two different types of work: (1) remove and pile overburden, and (2) remove and load the coal. The overburden is almost invariably much thicker than the coal; the stripping shovel is therefore required to do much more work than the loading shovel. The stripped material is expeditiously piled over the area from which the preceeding cut of coal has been taken. Loosened, the stripped material has a natural angle of repose approaching 45°; and in the loosened condition it occupies greater space than before it was disturbed. This greater space can most easily be obtained by increasing the height of the prismatic form into which it is piled. This requirement, in turn, demands that the stripping shovel be equipped with a long boom. The requirements for the loading shovel are only those of moderate lift and moderate capacity. Many of the standard shovels can fulfill these conditions excellently.

The width of cuts will depend upon the properties of the overburden. Commonly it is possible to leave the inside cut wall almost vertical, and unless disturbed by very violent weather conditions it will remain in that position long enough to complete the cut. With a long boom the stripping shovel can pile to a height of 30 - 35 feet or more. Under these conditions a cut 50 - 55 feet wide can be taken.

Sequence of cuts. The only serious technical difficulty is encountered in obtaining space for disposal of material from the first cut of the overburden. A coal outcropping near the top of a steep hillside offers an ideal situation for commencing operations, for the overburden can be easily disposed of. Following the stripping shovel, the loading shovel removes the coal which has been exposed. If haulage is by industrial railway the track may be laid either on the underclay directly up to the shovel, or upon the coal, in which

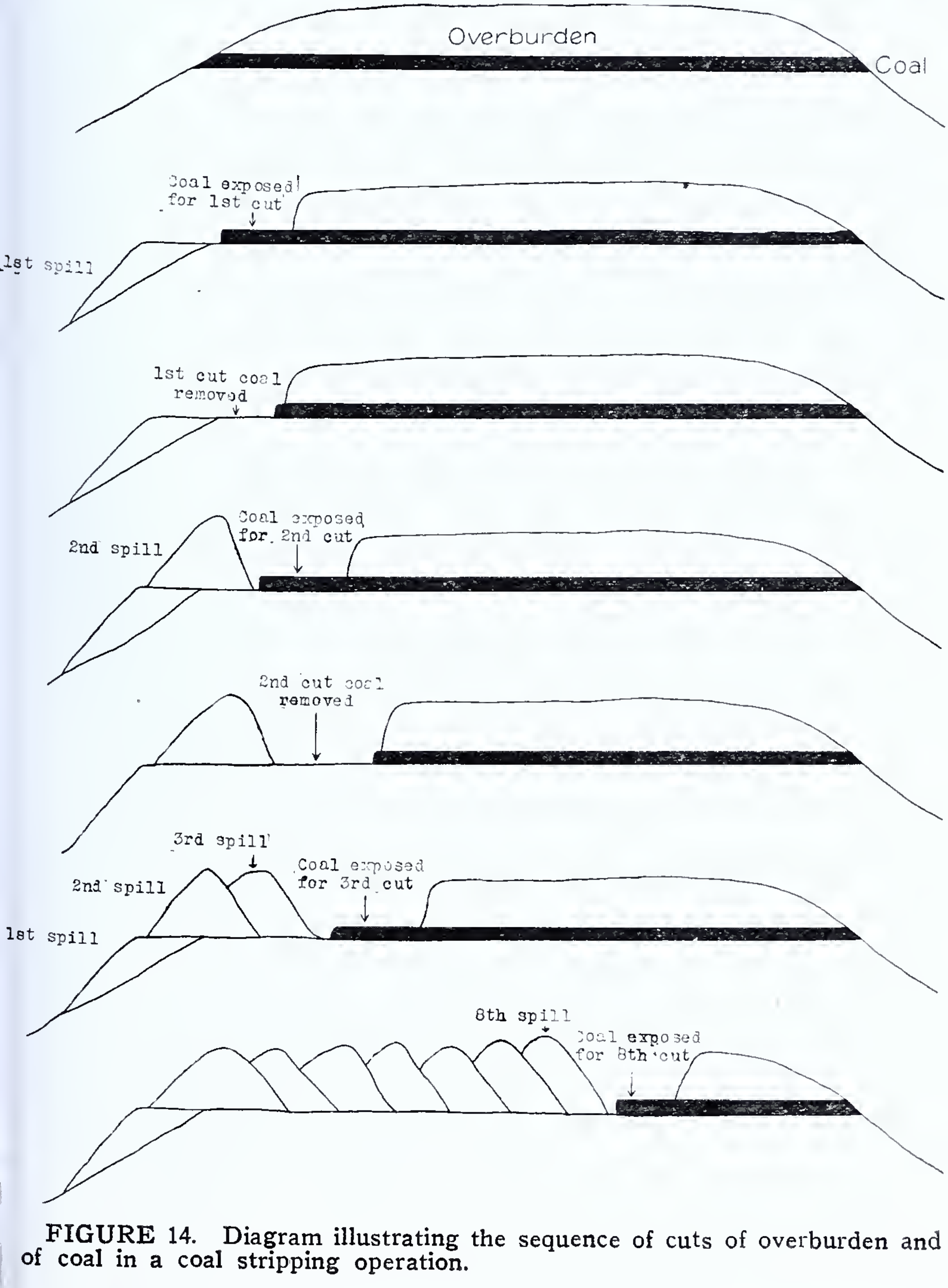


FIGURE 14. Diagram illustrating the sequence of cuts of overburden and of coal in a coal stripping operation.

case a small berm or shelf is left for this purpose. Figure 14 illustrates diagrammatically the sequence of cuts of overburden and of coal.

Salvage. It is economically impossible to pile the overburden otherwise than as a series of prisms, one edge being upward. The spill-piles therefore convey the impression of a multitude of small ridges, parallel, with intervening valleys. The slopes of the ridges are at the angle of repose of the material, the latter being loose, in platy fragments. The differences in elevation between the ridges and the valleys may be 5-15 feet, the whole being very irregular. The cost of leveling the surface would be far beyond the cost of adjacent tillable farm land at present, therefore the waste piles are at present utterly useless and unpleasant, unsightly scars.

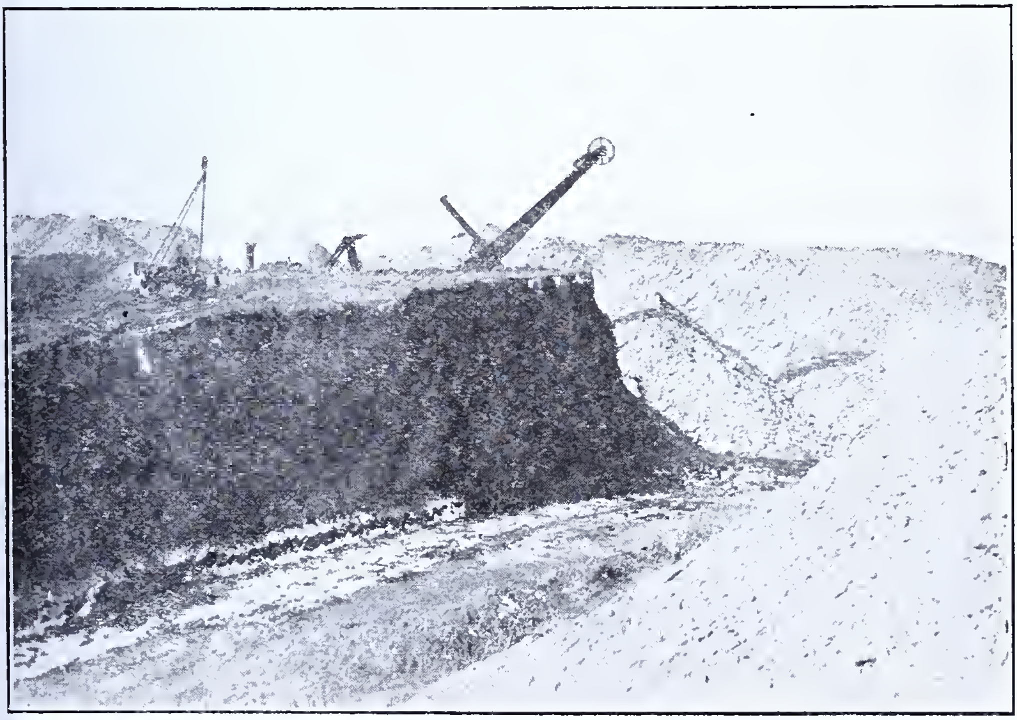
The suggestion is here made that these may be changed into very profitable, useful and pleasant places by conversion into evergreen plantations. The loosened material makes for ideal soil conditions upon disintegration of the shales, and inspection of spill-piles only a few months old shows how rapidly disintegration takes place. The same transportation systems which now take the coal to its destination could be used to take the evergreens to market. Immediately upon being planted the unsightliness would disappear, and in a surprisingly short time financial advantage would result.

Specific operations. The White Clay Mining Company carries on stripping operations in South Beaver Township about 2 miles southwest of Cannelton. From the shovels the coal is taken by industrial railway to loading station where it is dumped into cars on a spur of the Pittsburgh, Lisbon & Western Railroad. Despite the name of the operating company only coal is removed. The output amounts to about 700 tons per day.

The Beaver Finance Corporation (East Palestine, Ohio) carries on a similar although smaller operation in Darlington Township. The site of this operation is to the north of Darlington Road (Route 204) about 1 mile east of the Pennsylvania-Ohio State line. At this place the East Palestine coal, on which their operations are conducted, lies beneath 20 - 30 feet of stripping. The stripping shovel is a Marion, model 252, with 75-foot boom and 3½ cubic yard bucket; the loading shovel is a Marion, model 31, caterpillar traction, with a 36-foot boom and 1 cubic yard bucket. The entire output of this operation, upwards of 100 tons per day, is transported to market via motor trucks, the Darlington Road (Route 204) passing the property. The coal is used for domestic and manufacturing purposes in East Palestine, Ohio, Beaver Falls, Pa., and nearby communities.

Plate XI

A. Digging coal with steam shovel near Cannelton.



B. Stripping overburden and digging coal with steam shovel near Cannelton.

COAL ANALYSES.

Mine samples taken in the New Castle quadrangle in 1920-21 by representatives of the Pennsylvania Topographic and Geologic Survey were analyzed at the Pittsburgh Experiment Station of the U. S. Bureau of Mines. These were published in a bulletin[1] of the State Survey in 1925 and are printed here, with notes on the mines from which the samples were taken.

Analyses of mine samples

Locality, mine, coal bed, etc.	Sample.			Proximate.				Ultimate.					Air-drying loss.	Calorific value.		Softening temp. °F. §
	Laboratory No.	Kind.†	Condition.‡	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
BEAVER COUNTY																
Cannelton Station, ¼ mile north of; Robin Hood mine, Middle Kittanning bed (100 yds. in entry, from north pit mouth).	34,637	A	1	4.6	36.2	53.8	5.4	1.2	-----	-----	-----	-----	2.4	7,467	13,440	2,130
Same (on rib, 100 yds. in entry, from south pit mouth).	34,638	A	1	6.1	33.6	56.0	4.3	.7	-----	-----	-----	-----	3.5	7,328	13,190	2,230
Same (composite of samples 34637 and 34638).	34,659	A	1	5.4	34.9	54.8	4.9	1.1	5.6	75.1	1.5	11.8	3.0	7,394	13,310	-------
			2	-----	36.9	57.9	5.2	1.1	5.3	79.3	1.6	7.5	-----	7,817	14,070	-------
			3	-----	38.9	61.1	-----	1.2	5.6	83.7	1.7	7.8	-----	8,244	14,840	-------
¼ mile north of; Saratoga Fire Clay mine, Lower Mercer bed (face of 6 room, 2 left entry, 400 yds. from mine mouth).	34,653	B	1	3.8	36.7	48.3	11.2	3.8	-----	-----	-----	-----	2.0	7,033	12,660	2,090
Same (right rib, 400 yds. in main entry).	34,654	B	1	3.4	34.0	44.8	17.8	4.9	-----	-----	-----	-----	1.6	6,439	11,590	1,960
Same (composite of samples 34653 and 34654).	34,655	B	1	3.6	35.2	46.8	14.4	4.2	5.1	66.5	1.3	8.5	1.8	6,739	12,130	-------
			2	-----	36.6	48.5	14.9	4.4	4.9	68.9	1.3	5.6	-----	6,989	12,580	-------
			3	-----	43.0	57.0	-----	5.2	5.8	81.0	1.5	6.5	-----	8,217	14,790	-------
¾ mile west of; Pittsburgh-Cannelton mine, Upper Freeport bed (in main entry, 400 feet from mine mouth).	80,462	B	1	4.7	35.5	53.2	6.6	1.6	5.6	74.2	1.5	10.5	2.9	7,344	13,220	2,240
			2	-----	37.2	55.9	6.9	1.7	5.3	77.8	1.6	6.7	-----	7,706	13,870	-------
			3	-----	40.0	60.0	-----	1.8	5.7	83.6	1.7	7.2	-----	8,278	14,900	-------
1 mile northwest of; Cannelton-clay mine, Upper Freeport bed, (475 yds. in 1 right left room.	34,656	A	1	4.6	36.8	52.3	6.2	2.2	-----	-----	-----	-----	2.6	7,439	13,390	1,980
Same (face of 1 right entry, 500 feet from mine mouth)	34,657	A	1	4.4	37.8	51.5	6.3	1.8	-----	-----	-----	-----	2.2	7,417	13,350	2,160
Same (composite of samples 34656 and 34657)	34,658	A	1	4.5	37.0	52.2	6.3	2.0	5.5	74.2	1.5	10.5	2.3	7,411	13,340	-------
			2	-----	38.8	54.6	6.6	2.1	5.3	77.7	1.6	6.7	-----	7,767	13,980	-------
			3	-----	41.5	58.5	-----	2.2	5.6	82.2	1.7	7.3	-----	8,317	14,970	-------

1½ miles northwest of; Beaver-Cannel mine, Upper Kittanning bed (face of 1 right entry, main entry, 400 yds. from mine mouth).	34,650	B	1	3.5	38.8	49.9	7.8	3.1	-----	-----	-----	-----	1.5	7,444	13,400	1,960
Same (face of 22 left room, main entry, 400 yds. from mine mouth).	34,651	B	1	2.9	40.0	51.1	6.0	2.9	-----	-----	-----	-----	1.1	7,617	13,710	2,090
Same (composite of samples 34650 and 34651)	34,652	B	1	3.2	39.5	50.3	7.0	3.0	5.6	74.6	1.6	8.2	1.3	7,528	13,550	-------
			2	------	40.8	52.0	7.2	3.1	5.4	77.1	1.7	5.5	-----	7,778	14,000	-------
			3	------	43.9	56.1	------	3.3	5.8	83.1	1.8	6.0	-----	8,383	15,090	-------
LAWRENCE COUNTY.																
Wampum Station, 2 miles west of; Crescent mine, Middle Kittanning bed (face of main entry, 4,200 feet from mine mouth).	34,739	B	1	7.8	34.3	48.5	9.4	5.4	-----	-----	-----	-----	6.5	6,833	12,300	2,410
Same (face of entry, 15 left room, 3,900 feet from mine mouth).	34,740	B	1	6.9	32.4	49.8	10.9	1.9	-----	-----	-----	-----	5.0	6,778	12,200	2,540
Same (face of 9 butt entry, 1,700 feet from mine mouth)	34,741	B	1	5.7	33.4	54.3	6.6	1.9	-----	-----	-----	-----	4.1	7,244	13,040	2,410
Same (composite of samples 34739 to 34741 inclusive)	34,742	B	1	6.9	33.5	50.7	8.9	3.0	5.4	69.6	1.3	11.8	5.2	6,972	12,550	-------
			2	------	36.0	54.4	9.6	3.2	5.0	74.8	1.4	6.0	-----	7,483	13,470	-------
			3	------	39.8	60.2	------	3.6	5.5	82.7	1.5	6.7	-----	8,272	14,890	-------
2 miles southwest of; Vance country bank, 6-foot bed, (face of 2 face entry, 150 yds. from mine mouth)	34,736	B	1	3.8	38.2	51.9	6.1	2.6	-----	-----	-----	-----	2.2	7,483	13,470	2,130
Same (face of 4 face entry, 175 yds. from mine mouth)	34,737	B	1	3.8	38.6	52.5	5.1	2.4	-----	-----	-----	-----	2.1	7,517	13,530	2,190
Same (composite of samples 34736 and 34737)	34,738	B	1	3.8	38.4	52.2	5.6	2.6	5.5	75.0	1.5	9.8	2.2	7,522	13,540	-------
			2	------	40.0	54.2	5.8	2.7	5.3	78.0	1.6	6.6	-----	7,822	14,080	-------
			3	------	42.4	57.6	------	2.8	5.6	82.8	1.7	7.1	-----	8,306	14,950	-------

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[1] Coal Analyses, Pennsylvania Topographic & Geologic Survey, Bull. M6, pt. IV, 1925.

† A, mine samples collected by an engineer of the U. S. Bureau of Mines; B, mine samples collected by a geologist of either the U. S. Geological Survey or the Pennsylvania Topographic and Geologic Survey.

‡ 1, sample "as received" at the laboratory; 2, dried at a temperature of 105° C.; 3, moisture and ash free.

§ Figures in column 17 are the temperatures at which the cone of coal ash has fused down to a spherical lump when heated in the furnace in a slightly reducing atmosphere.

LAWRENCE COUNTY.

WAMPUM. CRESCENT MINE.

Analyses 34739 to 34742 (p. 165). A mine 2 miles west of Wampum on the P. R. R. Middle Kittanning coal. Roof, slate; floor, fire clay. Cover at point of sampling, 80 feet. Sampled at three points by E. G. Hill on June 18, 1920.

Sections of coal bed in Crescent mine.

Section	A		B		C	
Laboratory No.	34739		34740		34741	
	Ft.	in.	Ft.	in.	Ft.	in.
Coal	2	3¼	2	7	2	5½
Sulphur*		¾	--------	--------		½
Coal, sulphur and bone ("clod")	--------	--------		6	--------	--------
Coal		6	--------	--------		5
Coal impure ("clod")		3	--------	--------		3
Thickness of bed	3	1	3	1	3	2
Thickness of sample	3	0	3	1	3	7½

*Not included in sample.

At the time of sampling the daily output was 300 tons.

WAMPUM. VANCE MINE.

Analyses 34736 to 34738 (p. 165). A country bank 2 miles south of Wampum, on the P. R. R. Upper Freeport coal. Roof, shale, then sandstone; floor, fire clay. Cover at point of sampling, 30 feet. Sampled at two points by E. G. Hill on June 21, 1921.

Sections of coal bed in Vance mine.

Section	A		B	
Laboratory No.	34736		34737	
	Ft.	in.	Ft.	in.
Coal	5	10½	5	2
Bone*		½		½
Coal*		4		8
Thickness of bed	6	3	5	10½
Thickness of sample	5	10½	5	2

*Not included in sample.

BEAVER COUNTY.

CANNELTON STATION. BEAVER CANNEL MINE.

Analyses 34650 to 34652 (p. 165). Beaver Cannel Co's. mine, 1½ miles northwest of Cannelton station on the P. L. & W. R. R. Upper Kittanning coal. Roof and floor, slate. Depth at point of sampling, 200 feet. Sampled at two points by E. G. Hill on June 16, 1920.

Sections of coal bed in Beaver Cannel mine.

Section	A		B	
Laboratory No.	34650		34651	
	Ft.	in.	Ft.	in.
Bone cannel*		3		
Cannel coal*		2		
Cannel coal		8		8
Bituminous coal	2	0	2	2
Thickness of bed	3	1	2	10
Thickness of sample	2	8	2	10

*Not included in sample.

CANNELTON STATION. CANNELTON CLAY & COAL MINE.

Analyses 34656 to 34658 (p. 164). Cannelton Clay & Coal Co. mine, 1 mile northwest of Cannelton on the P. L. & W. R. R. Mahoning coal. Thickness of bed, coal, and samples, 2 feet 7 inches to 2 feet 9 inches. Roof, 8 inches bone, then slate; floor, clay. Depth at point of sampling, 60 feet. The bed was sampled at two points by L. D. Tracy on June 15, 1920.

In 1920 the daily output was 30 tons.

CANNELTON. PITTSBURGH-CANNELTON MINE.

Analysis 80462 (p. 164). Pittsburgh-Cannelton Coal Co's. prospect, a drift mine 1080 feet above sea-level, ¾ mile west of Cannelton on the P. L. & W. R. R. Upper Freeport coal. Practically horizontal. Roof, good shale; floor, soft clay. Sampled at one point on July 7, 1921, by Chas. R. Fettke of the Carnegie Institute of Technology, Pittsburgh, Pa.

Section of coal bed in Pittsburgh-Cannelton mine.

Section	A	
Laboratory No.	80462	
	Ft.	in.
Coal	1	1½
Black shale		½
Coal	1	1½
Black shale		½
Coal	1	3½
Shale*		1½
Coal*		3
Thickness of bed	4	0
Thickness of sample	3	7½

*Not included in sample.

Analyses of coal from other mines in this region are found in the reports of the Second Geological Survey of Pennsylvania. The mines mentioned probably were local banks which are not now in operation.

*Coal Analyses**

	1	2	3	4	5
				Lower Kittanning	
	Middle Kittanning	Upper Kittanning (bituminous	Upper Kittanning (Cannel)		Upper Bench
Water	3.090	1.780	1.160	1.620	2.200
Volatile matter	37.915	40.760	48.015	39.385	39.440
Fixed carbon	56.980	49.391	38.241	43.603	50.705
Sulphur	.495	3.379	.599	2.822	.825
Ash	1.520	4.690	11.985	12.570	6.830
Total	100.000	100.000	100.000	100.000	100.000
Coke	58.995	57.460	51.985	58.995	58.36

	6	7	8	9	10	11
	Lower Kittanning			Quakertown	Homewood	Sharon
	Lower Bench	Coke				
Water	2.400	0.010	1.930	2.030	1.190	3.790
Volatile matter	38.110	0.633	42.445	42.127	48.140	35.300
Fixed carbon	54.619	84.727	49.823	44.233	44.084	53.875
Sulphur	.791	1.994	1.832	4.087	1.951	.675
Ash	4.080	12.636	3.970	7.503	4.635	6.360
Total	100.000	100.000	100.000	100.000	100.000	100.000
Coke	59.490	------------	55.625	55.823	50.670	60.910

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*Pennsylvania Second Geological Survey Reports Q and QQ, 1878-9. A. S. McCreath, analyst.

Beaver County.

1. North Sewickley Township, Dougherty's mine, Middle Kittanning bed. Rept. Q, p. 277.
2. Darlington Township, Mansfield's mine. Bituminous coal from Upper Kittanning bed. Rept. Q, p. 277.
3. Darlington Township, Mansfield's mine. Cannel coal from Upper Kittanning bed. Rept. Q, p. 277.
4. Patterson Township, Ross & Smith mines near Beaver Falls. Lower Kittanning bed. Rept. Q, p. 278.
5. Patterson Township, Hulmes mines near Beaver Falls. Upper bench of Lower Kittanning bed. Rept. Q, p. 279.
6. Patterson Township, Hulmes mines near Beaver Falls. Lower bench of Lower Kittanning bed. Rept. Q, p. 279.
7. Patterson Township, Hulmes mines near Beaver Falls. Lower Kittanning coke. Rept. Q, p. 280.

Lawrence County.

8. Slippery Rock Township, Wm. Book land near northern border. Lower Kittanning bed. Rept. QQ, p. 36.
9. Mahoning Township, 1 mile northeast of Quakertown Station, Mr. Wright's mine. Quakertown coal. Report QQ, p. 65.
10. Taylor Township, Mr. Miller's bank near Mahoningtown. Homewood coal. Rept. QQ, p. 56.
11. Mercer County, near northwest corner of Lawrence County, Sharon coal on land of Mr. Williams. Rept. QQ, p. 69.

LIMESTONE.

Stripping. In the district studied the overburden is in most places of a shaly character and easily removed, provided its depth is not great. In small quarries the cover is usually dug by hand and removed by wheel barrow or cart. This method is slow and relatively expensive. For quarrying on a large scale, light tracks, dump cars, and steam shovel, should be provided.

In most cases the character of the overburden or cover is well adapted to steam shovel work. In stripping beds where the rock surface is irregular, it is frequently necessary to follow up the steam shovel with hand shovel work, in order to keep the product clean. The operators in each instance must decide what methods will give the best results in tonnage costs.

Mining. Usually the underground mining of rock is too expensive for road purposes. However, in several localities the Vanport limestone is being taken out in this way. Mining is practiced in the district by driving cross entries from a main passage and mining out rooms at right angles to the cross entries, alternating on opposite sides. Where the limestone is 18 feet thick, about 12 feet can be mined, leaving 6 feet for roof. Rooms vary in width from 25 to 40 feet and pillars from 20 to 25 feet, depending upon condition of roof and nature of cover. Rooms may be from 200 to 300 feet long.

The mining of limestone has been carried on in Pennsylvania for at least 30 years, but the subject has only recently received widespread attention. This method of operating permits the removal of clean stone, and permits continuous working in reasonable comfort regardless of weather conditions. Mining cost may be somewhat greater than quarrying cost under circumstances favorable to quarrying operations, but whereas quarrying operations are limited by increase in overburden mining operations have no such limit. It is therefore usually possible to erect a much larger crushing plant or cement plant in conjunction with a limestone mine than would be possible, in the same location, were quarrying methods followed. From another viewpoint, charges per ton of product not directly productive can usually be reduced by following mining methods.

As in all other successful mining operations, the methods and tools used in mining the Vanport limestone are largely dictated by local conditions. Some features are general, however. The beds above the limestone are shales; those below are sandstones or sandy shales which do not part readily from the limestone. The roof therefore requires support, and it is impossible to shovel from the floor without including undesirable material which will raise the silica content of the mine output. For these reasons it is necessary to leave the upper and lower portions of the limestone bed when mining. The thickness will determine the method of breaking, or stoping. Breast and overhand stopes are used where thickness permits. If power driven shovels be used the entire minable thickness may be removed as one operation. With air drills 15-20 feet of hole may be drilled per hour. Gelatin dynamite is an excellent explosive for this class of work. Blasting is done at the end of the shift. Power shovels are electric and air-operated, with either caterpillar, wheel or rail traction. The type, size, and model of power shovel will be determined by headroom and by size of working places, as well as by operating expense.

Uses. The Vanport limestone here is suitable in quality for

1. Road building. No other stone in northwestern Pennsylvania excels or even equals it in wearing qualities and cement value.

2. Fluxing stone. The low percentage of silica, phosphorus, and alumina in the Vanport limestone makes it available for this purpose.

3. Sintering stone. For this purpose the stone must be broken to a ¾ inch size.

4. Cement. The Vanport being high in lime and low in silica is largely used with blast furnace slag in the manufacture of Portland cement. Limestone, to have good cement value, should contain sufficient lime to bring the percentage in the mixture up to 75 per cent, should contain not more than 4 per cent magnesia, 6 per cent silica, no large amounts of aluminum or iron sulphides, and should not be too hard or too porous.

5. Lime. The Vanport is well adapted and largely used for lime, both for agricultural and commercial purposes.

VANPORT LIMESTONE OF LAWRENCE COUNTY.

By F. B. Peck

In Lawrence and adjacent counties the Vanport limestone is remarkably presistent and rather uniform in both thickness and character. In thickness it ranges from 14 to 23 feet, with an average in the majority of localities where it was examined (at outcrops or in quarries) of 18 feet. In most places several distinct benches or subdivisions in the formation can easily be distinguished, owing to somewhat pronounced changes in the lithological and chemical character of the rock. See figure 15. Usually the upper bench, 5 to 8 or even 12 feet thick, consists of gray, highly fossiliferous limestone, in which the bedding planes are rather widely separated and regular in character, giving this part of the formation a thick or heavy bedded appearance. Chemically it is reported to be somewhat impure, containing 70-75 per cent of carbonate of lime ($CaCO_3$), the remainder being mostly silica and alumina. This upper bench breaks with a conchoidal fracture into angular fragments, rudely equidimensional.

Below this upper bench usually occurs 2 feet of a more or less slaty variety of limestone which has a tendency to break in long flat pieces. This slaty character is exaggerated on weathering, for where the rock has been long exposed, the slaty character is clearly visible. Usually, however, where the rock is freshly broken, its slaty character is not particularly noticeable and would not detract materially from its good road building qualities.

Below this somewhat slaty horizon or bed usually comes 2 to 5 feet of purer limestone, the purest in the formation, said to contain 96 per cent $CaCO_3$. It is sometimes called the "Bull" layer or bed and sometimes goes by the name of the "20-inch" seam or bed. It breaks into equidimensional fragments and has an irregular or conchoidal fracture.

Below this bench of purer limestone lies 3 to 5 feet of dark blue limestone, having a rather thin and very irregular bedding which gives the limestone a decidedly warty or knotty appearance. It is

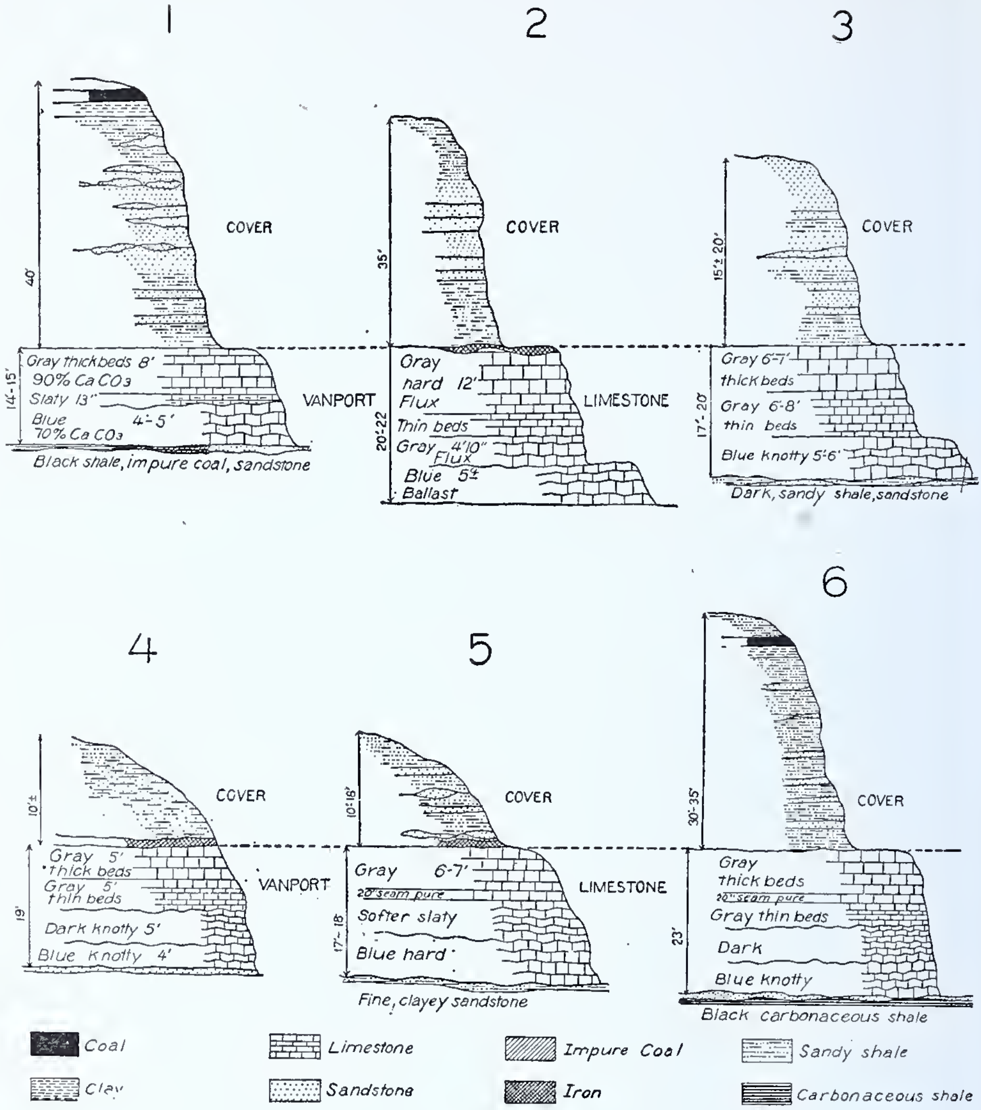


Figure 15. Cross sections of Vanport limestone quarries, Lawrence County.

1 Lehigh Portland Cement Co., New Castle.
2 Shenango Limestone Co., 1 miles south of New Castle.
3 Interstate Limestone Co., 1½ miles northwest of Chewton.
4 Duck Run Limestone Co., 3 miles north of Ellwood City.
5 Rose Point Limestone Co., Rose Point.
6 Clydesdale Stone Co., Ellwood City.

usually very hard and splintery, and breaks into irregular fragments. Chemically it is somewhat impure and is reported to average 74 to 76 per cent $CaCO_3$. The bottom layer, a foot or less in thickness, is often flinty in character and seems to be decidedly impure. It is sometimes referred to as "bottom rock."

These various horizons or benches are not always distinguishable in different quarries. Occasionally, however, the upper gray limestone with its thick regular bedding comprises nearly two-thirds of the entire thickness of the Vanport and can be quickly and easily distinguished from the blue knotty limestone below with its thin, irregular bedding. The upper gray portion is the rock best suited for flux, while the lower bench of blue limestone is less suited to that purpose and is sometimes left in the quarry floor to be quarried later for ballast or concrete. Both the gray and the blue as well as the slaty beds, are suitable for cement making, and occasionally the blue is sold as flux for open hearth furnaces.

Description of Individual Exposures.

The Vanport limestone is the only rock suitable for road metal in Lawrence County. In Beaver County it occurs too low down, i. e. too near drainage, and consequently under too heavy a cover, to be conveniently quarried. But northward in the southern part of Lawrence County it gains an elevation of 1000-1050 feet, and is far enough above drainage and near enough toward the top of the hills to be economically stripped or mined by underground methods for flux, ballast, concreting, and lime, or cement. Northward about New Castle it gains an elevation of 1100 feet and keeps it west of New Castle at Hillsville and at the Ohio State line. East of New Castle, in the eastern part of Lawrence County and the western part of Butler County, about Rose Point, Paynes, and Portersville Station, it lingers at or near 1200 feet. Across the entire width of Lawrence County, both east and west of New Castle, the limestone is found under a comparatively light cover and can therefore be economically stripped and quarried over relatively large areas. It will be noted that the large quarrying operations of Lawrence County are located east and west of New Castle. It is because the limestone in this latitude occurs well toward the tops of the hills under cover that varies from nearly zero to once, possibly twice, its own thickness and is seldom more than that. A few miles south of New Castle, as at Ellwood City and Wampum, the cover becomes so heavy as to be prohibitive for most quarrying operations and mining is resorted to, as at the Crescent Portland Cement Co's. quarry immediately south of Wampum.

A description of a few of these localities, with observations on the character and availability of the rock, will now be given.

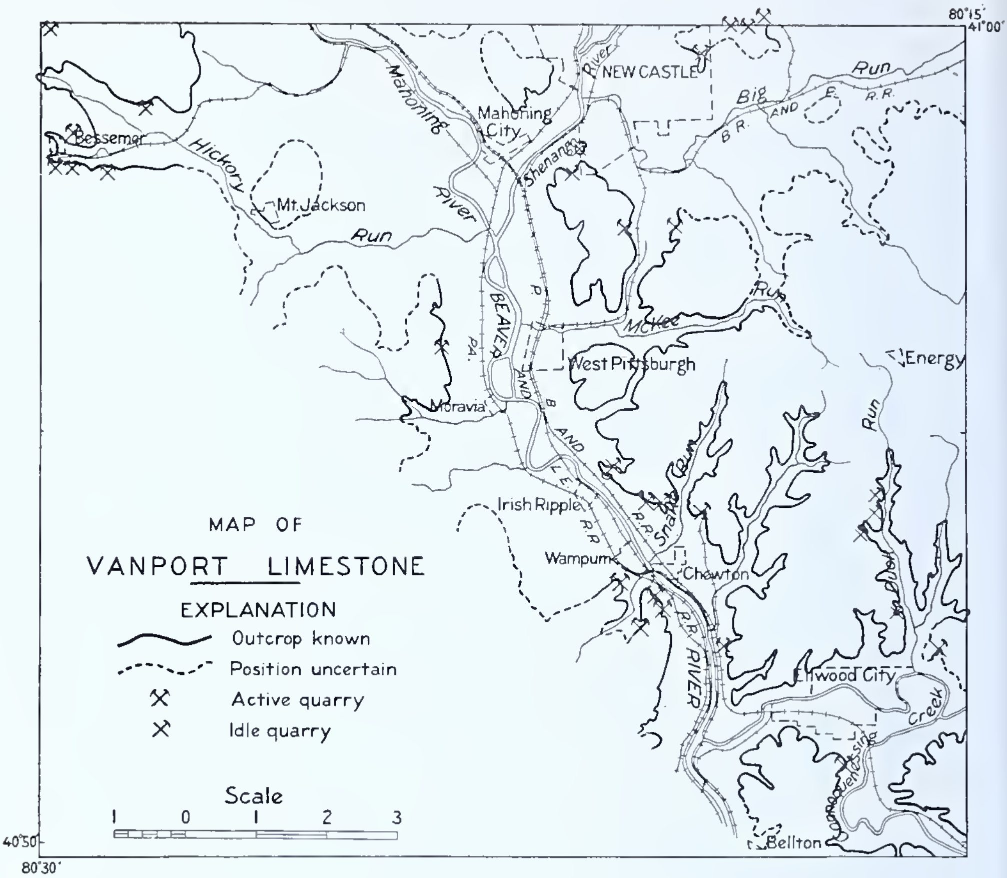


FIGURE 16. Sketch map showing outcrop and important workings on the Vanport limestone in the New Castle quadrangle.

New Castle. As described under the heading Portland cement, the Lehigh Portland Cement Company operates large quarries in the Vanport limestone just east of New Castle. The limestone there is 14 feet thick.

About 1 mile south of New Castle is the quarry of the Shenango Limestone Co. It is one of the best places in the New Castle region from which to derive an immediate and large supply of limestone for road metal. When the concern was in operation a considerable tonnage was supplied for flux, ballast and roadmaking. Operations were discontinued about 1920. The quarry face is 2500-3000 feet long. The limestone here is 20 to 22 feet thick and is quarried in two benches. The upper bench consists of about 12 feet of gray limestone, the lower 4 or 5 feet of which is thin bedded. This upper bench has been quarried in the past, chiefly for flux. The lower bench, which is about 5 feet thick, is blue, exhibits the usual irregular bedding of the lower part of the Vanport limestone, is hard and knotty and not suitable for flux, hence has been left in the bottom of the quarry to be quarried later from time to time for ballast or road metal.

The cover on this limestone is 35 feet thick at the deepest point. Toward the north end of the quarry it is much thinner, diminishing to 10 or 15 feet of disintegrated sandstone and shale, and is in places even thinner, so that there is a considerable area here that could be easily and inexpensively stripped.

All of the beds in this quarry seem of suitable character for road building.

The company was equipped with all modern appliances for quarrying on a rather large scale, including drills (both pneumatic and churn), steam shovel, and a crusher of several hundred tons daily capacity.

Three-fourths of a mile northeast of New Castle Junction, on a farm of 50 acres owned by a Mr. Cooper is an old quarry, formerly leased by the Geo. W. Johnson Limestone Co. Immediately to the south there are from 10 to 12 acres of ground underlain by the limestone, which has been thoroughly tested and said to be of good quality and thickness. In the old quarry but 8 or 10 feet of the limestone are exposed, the base of it being concealed by debris and water which has been dammed in to furnish water for stock.

Much of the adjacent territory to the north still is underlain with the limestone.

West Pittsburgh. North of West Pittsburgh, the limestone outcrops 1040-1060 feet above sea level, and one can see 8 feet of the rock, which is not its entire thickness. There is a small opening in it.

Just east of West Pittsburgh is an old quarry that has not been in operation since 1911. The quarry face is 250-300 feet long and exposes a thickness of 20 feet of good limestone. The cover for a distance of 200 feet back from the quarry face varies from 15 to 30 feet in thickness and consists of soft disintegrated sandstone and sandy shales. The elevation of the beds here is 1060-1080 feet. One foot of the inferior iron ore occurs above the limestone. The limestone outcrops to the north along the hillside for some distance from the quarry.

Half a mile south of Union Valley an outcrop of the limestone shows a thickness of 23 feet. This is the maximum for the Vanport limestone in Lawrence County, so far as observed.

Chewton. Half a mile northeast of Chewton are the old quarries of the Lawrence Limestone Co., previously owned and operated by the Geo. W. Johnson Limestone Co., New Castle, Pa. These quarries, which are extensive, have not been operated since 1919 and the spur from the Baltimore & Ohio R. R. has been removed. The old quarry face exposes the limestone for 1000 feet or more, the average thickness being 12 to 14 feet.

The cover, which at the quarry face is 15 to 40 feet thick, increases rapidly up the slope of the hill to 70 feet at 200 feet from the quarry face.

This rapid increase in cover was probably the reason for the abandonment of the quarry. Coal has been mined from a bed 80 to 90 feet above the limestone.

Half a mile northwest of the previous locality is another old quarry of considerable extent. The limestone here is 15 to 20 feet thick. The upper 10 - 12 feet has been quarried, probably for flux; much of the lower bench, 5 feet thick, which consists of hard blue limestone, has been left in the quarry floor, and would be available for road metal. This rock extends back under the old waste heaps, where it could be easily recovered. The cover over the limestone here is 25-30 feet thick and consists of thin bedded sandstone.

One mile south of Chewton on the east bluff of Beaver River the burgh Limestone Co. and the Lawrence Limestone Co. The quarrying operations of the two companies developed one continuous quarry face about 1¼ miles long. These quarries have not been worked since the World War.

At the south end the limestone is 18 to 20 feet thick and consists of two benches, the upper 12 feet being gray and the lower 6 blue. At this end of the quarry for a stretch of 1500 feet along the quarry face, the rock is too highly siliceous for flux. The rock, however, is perfectly suited, as it seems, for road metal. There are 30 to 40 acres of ground that could easily be stripped and quarried, and hundreds of thousands of tons of rock already broken or ready to be quarried. The cover along the quarry face is 20 - 30 feet thick and increases to 50 feet, 200 feet back from the quarry face.

At the north end of the quarry the rock is suitable for flux, the upper 12 feet of gray limestone was shipped for flux in Bessemer furnaces, while the lower 6 feet of blue rock was used in open hearth furnaces. All the rock from this part of the quarry was thus sold for flux, most of it being shipped to Sharon and East Johnstown.

One mile south of Chewton on the east bluff of Beaver River the Consolidated Stone & Mining Co., New Castle, began quarrying the Vanport limestone in 1920. The bed is 18 - 20 feet thick in a 200-foot face. In 1925 a mine was opened in this limestone, and in 1926 had a main heading more than 1000 feet long and was producing 1000 tons daily. All of the limestone is taken except 2½ feet at the top which is left to support the roof. Air drills are used in the mine and loading is done by an air-operated Erie, type B. tunnel shovel. Steam and gasoline locomotives are used for haulage to the plant. The primary and secondary crushers are Gates gyratories. The product is sold largely for concrete aggregate and is shipped both by rail and by truck.

The company also makes quick lime and hydrated lime in two updraft shaft kilns on the railroad below the quarry.

Duck Run. The quarry of the Duck Run Limestone Co., owned by the Harmony Mercantile Co., Eidenau, Pa., three-quarters of a mile south of Duck Run, is not in operation though equipped with tracks, cars, and a small crusher. The quarry face is 200-300 feet long and exposes 18-19 feet of good limestone.

The cover at the quarry face varies from 5 to 15 feet and increases to 30 feet 100 feet back from the face. Conditions for further operation here are favorable.

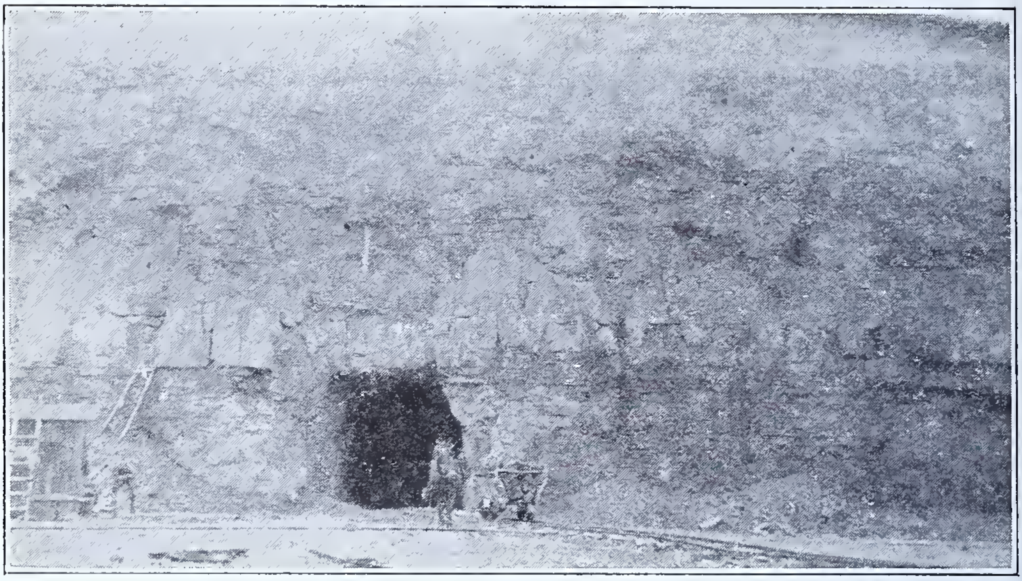
Ellwood City. Just south of Ellwood City is the extensive quarry of the Clydesdale Brick & Stone Co. The limestone formation here reaches its maximum thickness so far as observed in Lawrence County, consisting of gray with underlying blue beds, which together measure 23 feet. The cover, which is 30 to 40 feet thick, consists of thin bedded shaly sandstone and greenish gray sandy shale with a seam of coal and a thick bed of clay about 30 feet above the surface of the limestone. This cover is stripped and manufactured into paving brick in the company's brick yard. The limestone was quarried until the overburden became too great. Since 1925 it has been mined by five drifts averaging 400 feet long, from which rooms are driven. Four feet of limestone is left in the roof and 17 feet taken (Plate XII, A). Air drills are used, loading is by hand, mine cars are hauled out by horse, and delivered to the plant by Plymouth gasolene locomotive. About 400 tons of crushed stone in 4 sizes are produced daily for road metal. The crusher is driven by bought electric power. A short spur brings railroad cars directly to the crusher bins.

The elevation of the limestone in this quarry is approximately 1020-1040. There is a perceptible dip to the west however, for 1 mile to the west from this point, the limestone has an elevation of 980 to 1020.

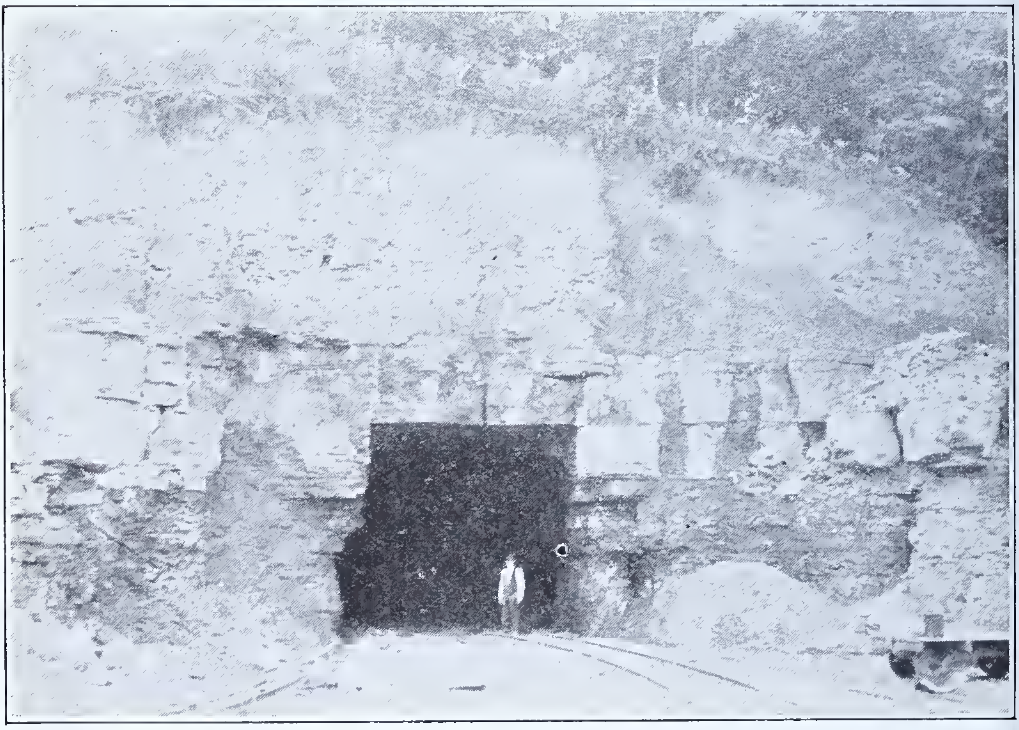
North and northwest of Ellwood City there are many outcrops of the Vanport limestone. Small quarries have been opened in several places.

Wampum. Half a mile south of Wampum a cable tramway crosses the highway, carrying limestone to the Crescent Portland Cement Co. plant on the river bank. The development of the Vanport limestone at this point is extensive for rock has been quarried here for 50 years. The limestone is 21 feet thick and the outcrop has been quarried back to heavy cover for about ¾ mile around the face of the ridge between Beaver River and Wampum Run. From the northern end of this ridge the cement company has driven a main heading south 4,000 feet and has mined the limestone from underneath the ridge. A steel bridge 150 feet high across Wampum Run gives access to the limestone in the ridge extending from Wampum to Coverdale, the outcrop has been quarried for several hundred yards at the north end of the bridge, a large heading is being driven into the ridge, and the limestone is being mined underground. (Plate XII, B.)

PLATE XII



A. Vanport limestone mine of Clydesdale Stone Company, Ellwood City.



B. Vanport limestone mine of Crescent Portland Cement Company, Wampum

Newport. Half a mile east of Newport (Irish Ripple) is an extensive quarry formerly worked by the Inter-State Limestone Company, now the property of the Carbon Limestone Company, of Youngstown, Ohio. Three benches are distinguishable, all apparently suitable for road material. The usual gray and blue varieties of limestone are typically developed.

Eastward from the northwest end of the quarry, around the end of the ridge, there seems to be a considerable acreage of good stripping ground, where the cover would be light. At the southern end of the quarry considerable rock has been stripped.

It is understood that this property is about 200 acres, extends to the middle of Beaver River, and as the company owns other quarries this is being held for future development. It has not been worked since about 1915.

Moravia. On the farm of Mr. F. W. Cochran, 1½ miles west of Moravia, the Vanport outcrops in the field north and west of the house at an elevation of 1050 feet. This tract has been drilled by the Crescent Portland Cement Co., and 16 feet of limestone is reported.

On the farm of Mr. Kelso, 1 mile northwest of Moravia, the limestone outcrops again at an elevation of 1050 feet. The beds here seem to lie between 1030-1050. Northward from here on the farm of Mr. E. O. Duff, there is an exposure of 4 feet of limestone at about the same elevation.

On the farm of Mr. A. R. Bright, half a mile north of Kelso's, is an old limestone quarry, which about 1890 was worked for flux. The quarry was an extensive one, extending to the north along the side of the hill. About 10 feet of gray rock was removed, leaving about 5 feet of blue rock in the bottom of the quarry. The total thickness is 15 feet or more. The cover at the quarry face is from 10 to 15 feet thick and consists of soft glacial debris. It slopes gently upwards to the west and 200 feet from the quarry face is but 20 or 25 feet thick.

Bessemer. West of New Castle near the State line, the limestone gains an elevation of 1100 feet. It maintains this elevation with surprising persistency, or rather we should say, that erosion has discovered the relatively hard, resistant Vanport limestone, which here assumes a horizontal attitude over a large area, the limestone being the controlling factor in the topography. It is a great bench-maker or terrace-maker wherever it gains enough elevation above drainage to influence the topography.

In the region about Bessemer and Hillsville, and north from these places, the soft friable sandstones and sandy shales that form the cover of the limestone, have been removed. North of Mahoning River most of the limestone has also been removed, residual patches of it remaining in the top of the hills.

The Bessemer Limestone & Cement Company, besides making Portland cement, quarries large quantities of Vanport limestone for blast furnace and foundry flux and for crushed stone. Quarry No. 5 of this company is just north of Bessemer, about half a mile long. The cover here is glacial drift which is 10 to 25 feet thick. The limestone is 22 feet thick and glacial scratches running S. 30° E. on its surface are splendidly developed. Steam shovels, both railroad and caterpillar, are used for stripping and for handling the rock. Steam and electric haulage are used. Just south of Bessemer this company operates a quarry with a face about one mile long. A considerable thickness of glacial material is removed by steam shovel, uncovering the shales over the Vanport limestone. This shale is loaded by steam shovel on a train hauled by steam locomotive, and used by the local brick plant. Removing the shale exposes to the limestone, which is drilled, shot down, and loaded out the same as the shale. The crushers and washeries where the product of these quarries is prepared for market are west of the cement plant. The gray rock is sold as flux. The blue rock is crushed and screened to four sizes, viz., 2 inch, 1 inch, 5/8 inch, and "sand." This crushed and sized blue limestone is sold to the State Highway Department for road material.

The capacity of the crushing plant is about 100,000 tons per month. All crushing units are Allis-Chalmers gyratory crushers, the sequence being No. 24, No. 8, and No. 7½ or No. 4. Screenings are further sized by a Jeffrey type B, 42 by 48 inch hammer mill, which has a maximum output of 150 tons per hour.

The Pittsburgh Crucible Steel Co. also quarries limestone here. Their quarry 1½ miles northeast of Bessemer has been in operation since about 1900 and now has a face nearly half a mile long. Here too an overburden of glacial material 20 feet thick is stripped by steam shovel, but there is little or no shale between it and the limestone. The upper 15 feet of gray rock in this quarry is used for flux and the lower bench, 5 feet thick, is quarried for concreting and road material, some of which latter is used by the State Highway Department.

North of Bessemer and just outside the quadrangle in the vicinity of Hillsville the Vanport limestone is quarried extensively by several companies.

PORTLAND CEMENT.

Three of the Portland cement plants in the small group in western Pennsylvania are in the New Castle quadrangle. Their location here is based on readily available and suitable limestone, shale, and coal, and on a large market. Cement manufacture in western Pennsylvania began at Wampum about 1877. The present capacity of the three plants is about 3,000,000 barrels yearly.

PLATE XIII

A. Portland cement plant of Bessemer Lime & Cement Co. at Bessemer. Crushed stone plant on left and cement silos on right.

B. Limestone quarry No. 5 of Bessemer Lime & Cement Co. at Bessemer. Stripping 25 feet of shale to get 19 feet of limestone.

C. Limestone quarry of Pittsburgh Crucible Steel Co. at Bessemer. Steam shovel stripping heavy overburden in middle distance.

Lehigh Portland Cement Co. Just east of New Castle are the extensive quarries of the Lehigh Portland Cement Co., formerly operated by the New Castle Portland Cement Co. The limestone here is under a cover of sandstone and sandy shale, with a coal bed underlain by fire clay at the top, and 30-40 feet above the top of the limestone. This coal bed is probably the Lower Kittanning, and is 20 to 30 inches thick. This shale furnishes the necessary clayey ingredient which is mixed with the limestone to form the proper mixture of raw materials necessary in the manufacture of Portland cement. Figure 15 shows the heavy cover on the limestone.

The limestone is here 14 feet thick and shows the several benches or sets of beds which are rather typical of the Vanport limestone everywhere in Lawrence County. The upper bench or set of beds is gray and consists of thick or heavy beds with rather even bedding planes. The limestone is hard and breaks with an uneven fracture into angular fragments. Chemically, it is reported to have a $CaCO_3$ content of 74.76 per cent. This upper bench is 5 feet thick. The succeeding bench is also gray and hard but has a higher content of $CaCO_3$ (96 per cent). The quarrymen occasionally refer to this bed as "Bull limestone." The lowest bench is darker and somewhat impure, having 70 per cent $CaCO_3$. The bedding is irregular and the rock has a warty or knotty appearance due to this irregular bedding. Its thickness is 4 to 5 feet.

Below this lowest bench comes 1 foot of black sandy shale which is followed by 1 foot of impure coal.

The capacity of the plant is 2,200 barrels daily, the dry process is used, and only straight Portland cement is manufactured.

This company has a central crushing plant for its three cement mills in this vicinity. This crushing plant is equipped with a Traylor bulldog 42-inch crusher (No. 21), followed by 36″ by 42″ Jeffrey mills. These discharge on a belt which carries the stone to storage bins. From there it is tapped into cars holding 17 tons and distributed to the three different plants. The shale is reduced to ½-inch mesh in a 9-foot dry pan of the American Clay Working Machinery Co. At the No. 3 plant on the outskirts of New Castle the mixed shale and limestone goes through 55-foot driers, seven 3-roll Griffin mills, and two Raymond mills. It is then ready for the kilns, of which there are four 125 feet long. They taper from a diameter of 7½ feet to 6½ feet. The clinker is elevated to 4 Mosser coolers and conveyed to the gypsum building where a suitable mixture is prepared for the final product. This passes in order to 1 Mosser pot-crusher, and 1 7-foot shale pan, and finally to 18 30-inch Griffin mills and 4 Bonnot tube mills.

The slack coal used for the kilns and for the various driers is passed through Mosser driers 50 feet long, and finally through 2 Raymond mills before storage in the bins of the kiln house.

Bessemer Limestone & Cement Co. In 1919 the Bessemer Limestone & Cement Company took over the assets of the Bessemer Limestone Company, which was organized in 1887 to quarry the Vanport limestone at Bessemer in the northwest corner of the quadrangle. The present company markets large quantities of limestone and Portland cement. The limestone used in the cement plant is screenings from the crushing plant, and as much larger stone as is necessary for full production—the shale is part of the overburden which has to be stripped to get at the limestone, which is 22 feet thick. The wet process is used, slurry being made by 3 Allis-Chalmers No. 726 wet Compeb mills. The stone is burned in 3 kilns, each 235 feet long. Of this length the first 175 feet is 10 feet in diameter, the other 60 feet being 8 feet in diameter. The nominal rating of the 3 kilns is 4,000 barrels of cement clinker per 24 hours. The cement is ground by 4 Allis-Chalmers No. 726 and one No. 622 dry Compeb mills, after which the cement may be stored in 22 reinforced concrete silo-type bins, the total capacity of which is 250,000 barrels. Packing is done by 8 Bates valve bag packing machines, the total maximum packing capacity being 1500 barrels of cement per hour. One Bates machine will pack 1500 barrels in 10 hours. The capacity of the plant is about 1,500,000 barrels annually.

Crescent Portland Cement Co. The Crescent Portland Cement Company operates a plant on the site of one of the earliest cement mills in the country, that of the Wampum Cement Company, Limited, where Jno. K. Shinn & Bros. were making natural cement as early as 1877. The plant is on the west bank of Beaver River half a mile below the bridge at Wampum. Shinn used a mixture of Vanport limestone with clay from the river terrace. The present company uses the clay shale from the bed immediately overlying the limestone.

The limestone here is 21 feet thick. The cover ranges from a few feet at the extreme northern end of the quarry to 50 or 60 feet at its deepest point about midway along the quarry face. As the amount of silica and alumina in the limestone is too low for the raw mixture, the sandy shale that overlies the limestone is added in sufficient quantities to give the proper percentages of lime carbonate, silica and alumina to the raw material. Thus a part of the overburden is utilized in the manufacture of the cement. The cover is not stripped from the limestone, but the limestone is mined by underground methods, the upper 3 or 4 feet being left to support the roof. The main heading in this mine has been driven south about 4,000 feet. So far as observed, this is the only place in Lawrence County where the limestone is being taken by underground methods. The mine entry at heading No. 3 and the shale and sandstone overlying the limestone are shown in Plate XII, B.

The outcrop of the limestone has been quarried for about three quarters of a mile, extending around the northern end of the ridge and southward along its western side. Here the cover is thin and about an acre of limestone has been stripped. This was originally a separate quarrying proposition.

All the rock quarried or mined is used in cement manufacture. These materials are transported from the mine to the plant by an aerial tramway which is 3,300 feet long between loading and discharge terminals and carries 1200 tons daily. The shale is dried on an open furnace under a shed.

The shale and limestone are then separately crushed and elevated to rotating cylindrical driers from which they pass to automatic scales where the two materials are combined in the correct proportions for cement. The mixture then is finely ground in Traylor tube mills, from which it is lifted by a current of air. It then passes to rotating kilns measuring 8 by 125 feet where it is burned to clinker by a blast of pulverized coal. One of the kilns is equipped with a 54 by 10-foot section. Part of the fuel is obtained from the Crescent mine near Coverdale (Upper Kittanning) and part purchased in the Pittsburgh district. The cooled clinker is first fed to a pot crusher and Hercules mills and then to tube mills where it is reduced to powder by iron balls and steel slugs. The proportion of shale and limestone varies from time to time, usually 39 pounds of shale is mixed with 225 pounds of blue limestone or 45 pounds of shale with 200 pounds of the gray limestone. The final product is also analyzed and its strength is tested according to standard methods. The yearly capacity of the plant is about 1,350,000 barrels.

Analyses of Limestone.

The following analyses of Vanport limestone at New Castle were kindly furnished by Wm. H. Kleckner, superintendent of Mill No. 3 of the Lehigh Portland Cement Company.

Analyses of Vanport limestone from quarry of Lehigh Portland Cement Company, New Castle, 1910.

Sample No.	SiO_2	R_2O_3	CaO	$CaCO_3$	$MgCO_3$	V.M.	Fe_2O_3
1 Top	3.92	3.76	51.32	91.46	1.99	39.58	1.08
2 Top	2.46	3.40	52.14	93.11	2.30	40.04	1.98
3 Top	2.94	2.64	52.84	94.36	1.70	41.20	----------
4 Top	2.40	2.68	51.87	94.47	1.49	41.70	----------
5 Top	3.34	3.60	51.35	91.69	2.06	40.46	.96
6 Top	1.44	2.36	53.94	96.31	1.44	41.92	1.15
1 Middle	2.24	1.92	54.45	97.23	1.51	43.68	1.15
2 Middle	5.46	5.10	48.26	87.17	1.84	39.38	----------
3 Middle	2.40	2.44	54.16	96.72	1.65	41.70	1.15
4 Middle	2.14	2.02	53.94	96.31	1.68	41.80	----------
5 Middle	1.94	2.06	53.48	95.49	1.28	41.96	----------
6 Middle	2.62	2.46	53.73	95.90	1.44	41.38	----------
1 Bottom	7.82	6.04	47.24	84.36	1.91	37.34	----------
2 Bottom	5.16	3.92	50.18	89.61	2.09	39.64	1.98
3 Bottom	9.56	6.64	45.66	81.74	1.84	35.74	1.33
4 Bottom	5.78	4.26	50.20	89.84	2.00	38.48	----------
5 Bottom	5.30	4.06	50.37	89.95	1.59	39.52	1.64
6 Bottom	6.72	5.58	48.88	87.28	1.85	37.62	----------

Analyzed during 1914.

1 Top	2.50	2.40	52.14	93.11	1.62	40.68	----------
2 Top	2.36	2.59	52.73	94.16	----------	41.74	----------
3 Top	3.90	2.66	51.29	91.59	----------	40.36	----------
4 Top	1.60	2.46	53.68	95.89	----------	41.84	----------
6 Top	1.00	1.60	54.42	97.21	----------	42.50	----------
1 Middle	1.70	2.18	53.69	95.88	----------	41.46	----------
2 Middle	2.74	2.94	53.05	94.73	1.43	40.70	----------
3 Middle	2.00	1.50	53.58	95.69	----------	41.40	----------
4 Middle	2.32	2.18	53.14	93.65	----------	41.00	----------
6 Middle	2.46	2.58	52.99	94.93	1.51	41.56	----------
1 Bottom	5.60	5.00	48.67	86.92	----------	38.46	----------
2 Bottom	5.30	3.60	49.79	88.91	----------	38.58	----------
3 Bottom	5.36	4.58	49.78	88.92	1.69	38.86	----------
4 Bottom	8.20	6.50	46.77	83.54	----------	36.14	----------
6 Bottom	8.58	6.50	46.22	82.57	----------	36.30	----------

The character of the different layers of the limestone at Wampum varies considerably as shown by the following analyses, kindly furnished by O. C. Hasse, chemist for the Crescent Portland Cement Co.

Analyses of Vanport limestone and cement materials.

	1	2	3	4	5
$CaCO_3$	93.30	92.20	75.00	84.82	82.68
$MgCO_3$	1.92	2.00	1.23	2.90	1.73
Fe_2O_3	1.82	1.72 }	9.50	4.25	5.80
Al_2O_3	1.00	1.16 }			
SiO_2	2.17	2.00	13.84	5.85	8.10
Total	100.21	99.08	99.57	97.82	98.31

The shale overlying the limestone at this place, and the cement manufactured have the following analyses:

Analyses of shale and cement.

	Shale	Cement
SiO_2	64.61	21.90
Al_2O_3	20.90	7.46
Fe_2O_3	9.98	3.84
CaO	.47	63.60
MgO	1.04	1.26
SO_3	1.93	1.01
Total	98.93	99.07

The following analyses by A. S. McCreath of the Second Geological Survey of Pennsylvania from areas several miles further south are of interest. (See Rept. Q, p. 283).

Analyses of the Vanport limestone at Vanport, Beaver County.

	1	2	3	4
$CaCO_3$	93.482	88.464	91.607	91.089
$MgCO_3$	1.544	1.445	1.566	1.587
Fe_2O_3 Al_2O_3	1.823	2.324	1.291	1.589
S.	.030	.097	.290	.047
P	.047	.029	.030	.040
Insoluble residue	2.770	7.030	4.780	4.800
	99.696	99.389	99.564	99.152

1. Severn's quarry, half a mile below Vanport, New Brighton township. Upper bench.
2. Powers' quarry, near Vanport, on the Ohio river. Top stratum.
3. Powers' quarry, middle stratum.
4. Tygart's quarry, half a mile below Vanport. Lower stratum.

Analyses of Vanport limestone of Lawrence County.

	1	2	3	4
$CaCo_3$	94.785	94.214	93.340	95.768
$MgCo_3$	1.369	1.732	1.460	1.097
Al_2O_3	1.187	.805	1.563	.632
S.	.123	.165	.123	.088
P.	.032	.020	.047	.017
Insoluble	2.080	2.790	3.070	1.970
	99.576	99.726	99.603	99.572

1. Moffit's quarry, 2 miles north from Croton. Compact; brittle; sparkling with calcite; bluish gray and pearl gray; with irregular fracture. (MM., p. 297)
2. J. K. Sinnn and Bros. quarry, near Wampum, Big Beaver township. Compact; brittle; sparkling with calcite; bluish gray. (MM., p. 297)
3. Green, Marquis and Johnson's quarries, near New Castle, Compact, brittle; sparkling with calcite; bluish gray, with irregular fracture. (MM., p. 298)
4. McCord's quarry, 3 miles northwest from Mt. Jackson, North Beaver township. Compact, brittle; sparkling with calcite; pearl gray, with irregular fracture. (MM., p. 298)

No. 2 is now the property of the Crescent Portland Cement Company, No. 3 is the locality now worked by the Lehigh Portland Cement Company, and No. 4 is in the vicinity of Bessemer.

The following analyses from the Shinn quarries at Wampum are by Robertson Bros., Pittsburgh. (See Rept. QQ, p. 48).

Analyses of Vanport limestone at Wampum.

	Top	Middle	Bottom
Silica	4.50	4.14	2.31
Sulphur	.06	.20	.17
Alumina	.21	.21	.24
Phos. Acid	.07	.05	.04
Sesquioxide of iron	1.77	1.77	1.18
Oxide of Manganese	.20	1.20	.22
Lime	49.31	50.16	52.04
Magnesia	.75	.42	.43
Carbonic Acid	40.54	39.87	41.72
Water and Organic matter	2.59	2.03	1.65
Total	100.00	100.00	100.00

I. C. White regards the sample of the blue layer as unrepresentative since the rock looks very earthy, and different from the top rock.

Analyses of Vanport limestone at Bessemer.

[Brier Hill Steel Co., analyst]

	1	2	3	4	5	6	7	8
SiO_2	2.18	1.74	2.44	2.26	2.17	2.28	2.08	2.15
Al_2O_3	1.95	1.00	1.75	2.09	1.47	1.63	1.18	1.62
Fe_2O_3	.57	.54	.29	.29	.55	.51	.68	.46
CaO	52.98	54.14	53.14	52.70	53.20	53.16	53.15	53.30
MgO	.37	.38	.38	.68	.43	.52	.39	.38
S	.050	.057	.056	.065	.049	.048	.045	.054
Phos.	.078	.028	.025	.077	.039	.032	.040	.045

1. No. 5 quarry, A bed. 2. No. 5 quarry, B bed. 3. No. 5 quarry, C bed.
4. No. 5 quarry, Blue bed. 5. Average of Nos. 3, 4, and 5 quarries.
6. No. 3 quarry. 7. No. 4 quarry. 8. No. 5 quarry.

The following analyses made in the laboratory of the Bessemer Lime and Cement Co. show variations in composition of the bottom bed of the Vanport limestone at Bessemer.

Partial analyses of bottom bed of Vanport limestone.

[J. H. Willahan, analyst]

SiO_2	10.58	9.78	5.14	6.60	7.00
Fe_2O_3	2.46	6.70	6.14	4.24	6.12
$CaCO_3$	78.54	81.68	86.80	86.33	83.70

CLAY INDUSTRIES.

Seven plants in the quadrangle are actively engaged in making clay brick from local materials. Other plants are using materials which are shipped in for making art tile, china, white ware and sanitary ware. One or two men may be digging and shipping fire clay. The annual output of common, face, and paving brick is valued at several hundred thousand dollars and gives employment to several hundred men. The companies using local clay or shale are:

Alliance Brick Co., Darlington
Beaver Clay Mfg. Co., New Galilee
Clydesdale Brick & Stone Co., Ellwood City
Darlington Brick & Mining Co., Darlington
Fiske & Co., Inc., Darlington
Metropolitan Paving Brick Co., Bessemer
Pittsburgh Clay Products Co., Beaver Falls

Companies mining and shipping clay in this region are J. B. White Clay Mine Co., Cannelton, and Francis Coal & Clay Co., Darlington.

Mining methods. The methods of obtaining raw material vary but little. The Lower Kittanning fire clay is mined from a shaft and a slope by the Beaver Clay Manufacturing Co., while other operators have drift entries. The mines are laid out on the room-and-pillar system and the clay is mined out from beneath the coal by drilling and blasting, after which the coal may be broken down. The roof above the coal is very poor, consequently the coal is left in place as long as possible. This condition occasionally results in the abandonment of properties or portions of mines before the complete recovery of the coal. Rooms in clay mines vary from 15 to 21 feet wide, and commonly the daily output amounts to 15 tons per man. The East Palestine clay is obtained by the same method, while the Brookville is mined in a small open pit, and the Scrubgrass is loaded from the bottom of quarries after the Vanport limestone has been blasted out. The shale over this limestone is excavated with steam shovels after removal of 5 to 20 feet of glacial clay.

Plant methods. Fire clay and shale go from mine or quarry to a primary crusher of either the jaw or roll type. Grinding is done in a dry pan 6 to 9 feet in diameter. Mixing clays may be added in the dry pan. The Lower Kittanning is reported to make better fire brick if mixed with an equal amount of imported Bolivar or other flint clay. Some "red" alluvial clay or shale is commonly added to get reddish effects, and buff is obtained by mixing 4 parts of Lower Kittanning fire clay to 1 of shale. A very tough brick results from combining 1 part Vanport shale with 3 parts of Scrubgrass fire clay. After being ground the clay is passed through 1/8 to 1/16-inch screens and conveyed to the pug mill. Several makes of pug mills are in use and the bar of clay emerging from the die onto a conveyor belt is cut automatically by machine into bricks.

Green bricks are dried in long tunnels heated by steam coils. Ten to 17 such tunnels are used, each holding from 10 to 15 small cars with loads of 450 to 550 brick on each. The total capacities of the driers are about 50,000 to 150,000 brick. The time of drying ranges from 12 to 36 hours.

Between 80 and 90 kilns are in operation, of which 70 are round, down-draft type. These are usually 30-38 feet in diameter and hold from 80,000 to 138,000 bricks. The square or rectangular kilns are of different sizes, culminating in that of the Metropolitan Paving Brick Co. at Bessemer which is 1600 feet long and has a capacity of 135,000 brick daily. This company also has 10 Wilson kilns which measure 81 by 15 feet and have 150,000 capacity. The Darlington Brick & Mining Company have a similar kiln measuring 45 by 20 feet and holding 100,000 bricks. The time required to burn a kiln varies with pattern and capacity of the kilns and kind of ware. The Wilson kilns are reported to need only six days. Some other kilns require 10 to 16 days. Cooling takes 8 to 10 days, and shrinkage is reported to average 10 per cent.

Brick manufacturers use much the same tools, machinery and processes. They are very open-minded, and exchange information freely. Each manufacturer is always welcomed at competitors plants; and this spirit coupled with the aggressive tactics of the brick making machinery manufacturers inhibits sharp practices and minimizes "trade secrets." When any marked advance is made in processes or machinery all manufacturers may benefit by it. Any premium is due to operating efficiency and quality of product.

The Alliance Brick Company, a newcomer in this district and a branch of the organization whose headquarters are at Alliance, Ohio, began operations at Darlington April 15, 1925. At this location the clay (No. 3) is reported as being "short" (i. e., somewhat lacking in plasticity) and being hard to work. Twelve circular down-draft kilns, having a capacity of 85,000-87,000 bricks each, are in use. Producer gas is used for firing the kilns. The layout is such that additional kilns may be added, as necessary. With 16 kilns the expected output would be about 70,000 bricks per day. A kiln is burned in 7 days at 2350° F. Both power and coal were purchased in 1925 but it is expected that in the near future the mining operations will furnish 50-75 per cent of the fuel required. The product is face brick and about 70 men are employed.

An innovation introduced into the district at this plant is the Hatfield-Penfield grinder, manufactured by the American Clay Machinery Company. This has open ends and heavy crushers and screens; the result of these features is that the pan is always empty, thereby raising the output to about 3 times that of other standard machines. The designers of this plant have seemingly availed themselves of all improvements in design and construction.

The Beaver Clay Manufacturing Company, at New Galilee, manufacture face brick only, and ship about 2½ million bricks per month. The colors which have been standardized are various reds, browns, buffs, and grays. Reds are produced by admixture of shaly material. Their fire clay is mined from a drift 1000 feet long. Nine feet of clay is taken out at the rate of 140 cars of 4500 lbs. daily. The shale is produced by quarrying operations on a bed which is here 14 feet thick. Local coals, ("Bungeye" and "six-foot)") mined by this company for other purposes, are not accepted for burning operations. For fuel for these operations the company operates mines at Cannelton, the coal ("No. 7") there being 32-34 inches thick.

Yard 1, construction started in 1902, consists of 5 rectangular and 8 round kilns. The largest rectangular has a brick capacity of 250,000, the others averaging 180,000, 160,000, and 90,000 respectively; the round kilns have a brick capacity of 90,000 each.

Yard 2, construction started in 1915, now consists of a full brick machining unit and 8 round kilns with an average brick capacity of 100,000 each.

The brick are dried in both yards by direct fired tunnel driers.

The kilns are the up-and down-draft type, and are burned off at a temperature of 1950° to 2100° F. Burning period extends from 7 to 9 days on the average. Pyrometers are used to measure the kiln temperatures.

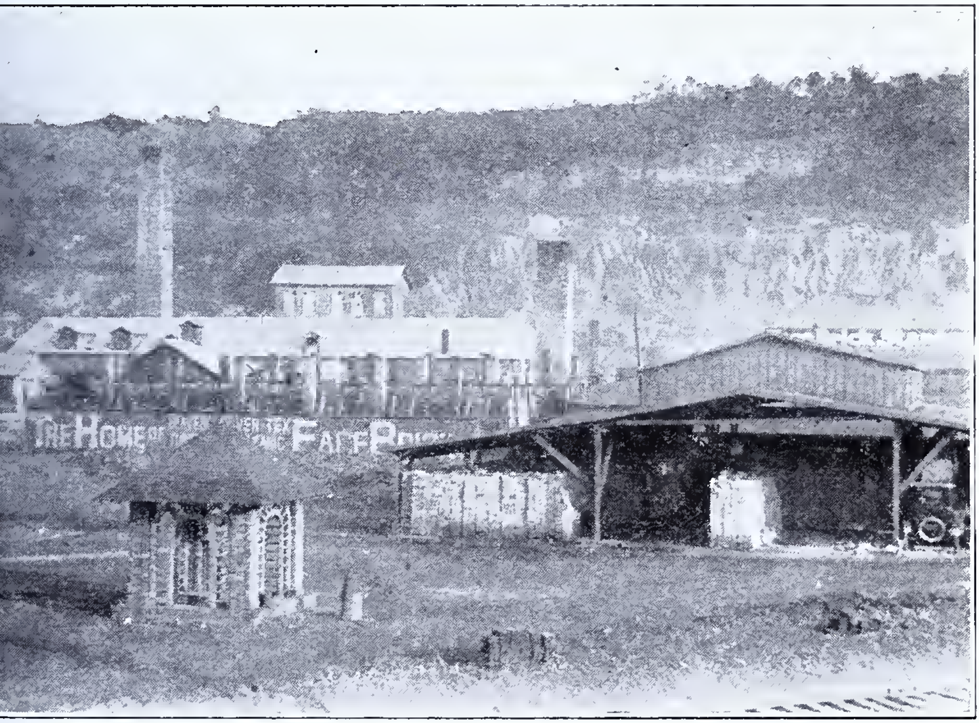
Both plants at the one location and under the same office management employ 125 men.

Clydesdale Brick & Stone Company (office, Jenkins Arcade, Pittsburgh) built a brick plant just south of Ellwood City in 1916 and began operating it in 1917. This is on the site of a Vanport limestone quarry previously operated by the Clydesdale Stone Co. The raw material is about 20 feet of shale resting on the Vanport limestone. The shale is dug by hand and hauled to the plant by a Plymouth gasoline locomotive. The product is mostly paving block, with some common building brick, burned in 12 38-foot circular down draft kilns with a capacity of 138,000 each. The output, figured as common brick, equals about 20,000,000 yearly. 65 men are employed in the shale pit and brickyard.

The Darlington Brick and Mining Company mine their own clay, the Lower Kittanning fire clay, and are removing the coal from that portion of their mine from which the clay has been removed. The plant is 2800 feet from the mine, and the workings are 3000 feet from the portal. Electric rack rail motors are used, for grades of 14

PLATE XIV

A. Face brick plant of Metropolitan Paving Brick Co., Bessemer.



. Part of face brick plant of the Beaver Clay Manufacturing Co., New Galilee per cent are encountered. Electric power is purchased. The sequence of treatment is crusher, grinding pans, bins, poidometers, pug mill, brick machine. From the cutting table the product goes to the drying tunnels and thence to the kilns. Both round and rectangular down draft kilns are used. The round kilns (2) have inside diameters of 30 feet and hold about 85,000 bricks. Seven rectangular kilns, 20 by 40 feet hold 90,000-95,000 brick apiece. Brick are burned at 2000 degrees Fahrenheit. It takes 2 days to fill, 6 days to burn, 4 to 5 days to cool, and 2 days to empty bricks. Occasionally a fan is used to accelerate cooling. Coal is used for drying the brick and gas for burning them. The product is 60,000 face brick daily. The plant was built in 1911. It employs from 60 to 70 men.

Fiske & Co., Inc., of Boston, bought out the Darlington Clay Products Company in 1926 and continued operation of the plant at Darlington. Fiske & Co. has brick plants also at Ridgway and Watsontown, Pa. The products of their plant at Darlington are gray and buff, rough and smooth texture face brick. The clay at this property is 8 - 12 feet thick, overlain by 28 - 30 inches of Lower Kittanning coal Following advanced practice the clay is removed leaving the coal as roof; then the coal is removed, permitting the roof to cave throughout the mined-out area. Except for the immediate top the clay is hard and somewhat sandy. The upper portion of the clay "weathers" readily and becomes so very plastic that the entire bed can be worked. In order that the mix may be uniform the product of several rooms is used simultaneously. Quality of products is further insured by the use of poidometers and disc feeders in making the mix. The brick are burned in a tunnel kiln in 55 hours and in periodic kilns in 6 days at a temperature of 2400° F.

Both natural gas and coal are used for burning, and drying is accomplished by using the waste heat. The capacity of the plant is about 72,000 brick per day. All labor is done on the piecework basis. About 80 men are employed. It is reported that brick manufactured in this plant have been used in every State in the Union.

The Metropolitan Paving Brick Company, of Canton, Ohio, has two brick plants at Bessemer. The face brick plant, built in 1902, is near the main road corners and west of the cement plant. It uses yellow shale from over the Vanport limestone, and has a capacity of 100,000 brick daily, from 12 rectangular, multiple stack Wilson down draft kilns. About eighty men are employed at this plant. The paving brick plant is at the east end of town. It was built in 1907, and enlarged to double capacity in 1914. Blue shale over the Vanport limestone is used. The shale storage house 300 feet long holds 25,000 tons. The crushing and grinding equipment consists of a 24 by 60 inch Fairmont type single roll, two 15 by 40 inch Anaconda type rolls, and Bonnot dry pans. The kiln at this plant is said to be the biggest ever built for burning brick. It is a re-designed Hoffman type continuous kiln, elliptical in shape, 1600 feet long with walls ten feet thick. It has induced draft, is fired from the side doors as well as from the top with a slack gas coal, and the temperature raised to approximately 2,000° F. The waste heat is used for preliminary drying. Thirty crews are employed on the kilns, ten firing, ten charging and ten emptying. The plant employs 225 men, makes 135,000 10 lb. paving brick daily (equal to 300,000 building brick) and handles 750 tons of ware daily.

The Pittsburgh Clay Products Company (office 1304 Keenan Bldg., Pittsburgh) is operating a face brick plant at Eastvale, a suburb of Beaver Falls. This plant was built in 1902 by the Douglas-Whistler Brick Company but has changed ownership several times in 20 years. The raw material is yellow shale dug by electric shovel in a quarry about 200 feet above the river. About 120 tons of shale is used daily. The plant has 10 circular and 2 rectangular down-draft kilns with a capacity of 1,000,000 brick monthly. Face brick of mingled shades, and straight red shades, are produced with a force of 40 men.

The company owns and is opening a mine on a hundred acre clay deposit.

Approximately ten days is required to burn a kiln, coal being used for fuel. At the present time the shale face brick are being burned off at approximately 2000°F.

Electricity is used for power. The plant is equipped with two Philips McLaren dry pans, Tyler-Hummer screens, E. M. Freese model P 4 pug mill, and a Freese Co. type K model K. D. brick machine having a capacity of 75,000 daily and a Steele No. 18 automatic cutter is being used.

SAND AND GRAVEL.

As the northern half of the quadrangle was covered by a glacier and the terminal moraine extends irregularly across the area described, deposits of sand and gravel are abundant. These deposits veneer the surface, fill old channels, and in places are upwards of 100 feet deep. They consist mostly of quartz sand mixed with pebbles of sandstone, limestone, and granitic rocks. The sedimentary rocks may be of local origin, but the igneous rocks were brought by glaciation from Canada.

Building sand has been produced by screening glacial deposits at a number of places. F. A. Bolinger of New Castle used to produce sand in this way on the east side of Mahoning River below the bridge at Covert Station, and E. C. McClelland dug sand on the west side above the same bridge and 60-70 feet above the river.

Other places near New Castle where sand and gravel have been dug for local use are: at Mahoningtown where there is a pit face 70 feet high (No. 186), west of Rigby (No. 185) about 40 feet of sand and gravel, at No. 180 a 15-foot bed with 6 feet of fine clean torpedo sand in the middle, and along Big Run (No. 179) is a deposit 60 feet thick.

The Universal Sand Company for several years has been digging sand and gravel for building purposes and railroad ballast in a glacial deposit 2½ miles southeast of the New Castle square near Joyce. This deposit directly on the B. R. & P. R. R. was 50 feet deep and covered 50 acres. It was worked out and the plant dismantled in 1926 preparatory to developing a 500 acre tract between Moravia and Lawrence Junction on the Pennsylvania Railroad. Washed sand and gravel will be produced from an extensive glacial deposit on both sides of the highway. The gravel in the glacial deposits along Beaver River is mostly sandstone, but contains also fossiliferous limestone, iron carbonate nodules, granite, gneiss, and quartzite.

The Mahoning Valley Sand Co., of West Pittsburgh, is digging sand and gravel 1½ miles south of that place where a small run comes out from the hills on the east. The company has a lease on 130 acres in which the glacial deposit is 20-60 feet deep. The deposit is dug by a drag line scraper drawn by a stationery electric motor. The scraper empties into a hopper which spills onto a belt conveyor 225 feet long. By this belt and another belt 350 feet long the material is delivered to a washing plant on a railroad spur. The product is washed building sand and gravel, all closely screened to various sizes. The daily capacity of the plant is about 400 tons or 8 cars.

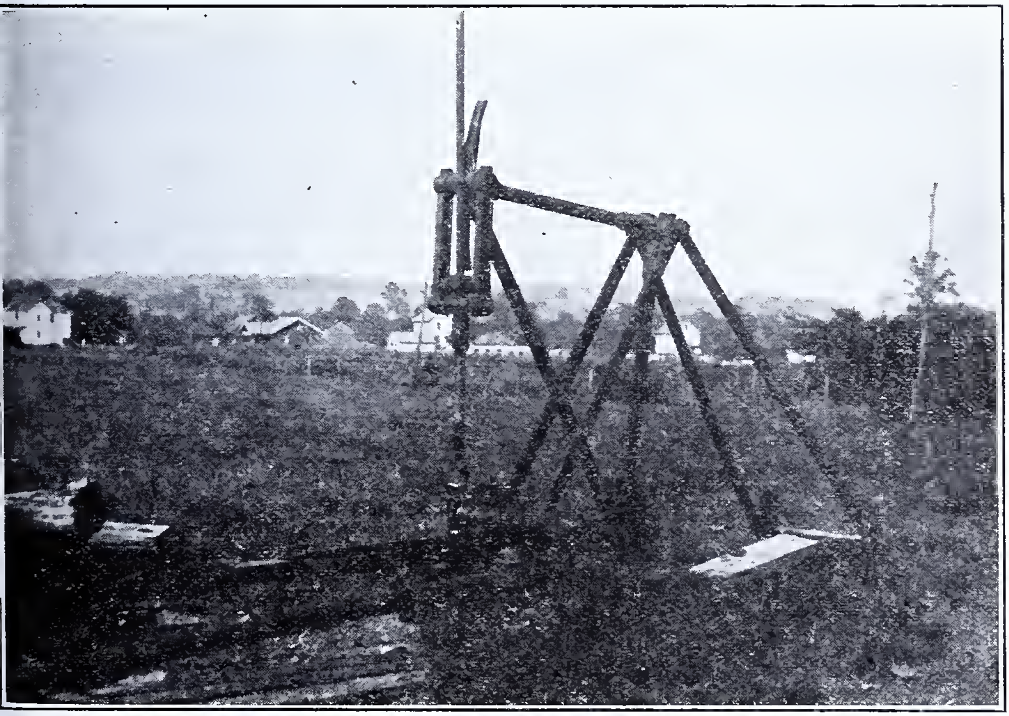
Production began years ago at the railroad and has progressed several hundred yards away from the main line. A spur extends to the washing plant, and the system of conveyors with the shorter belt in the quarry movable is a novel and efficient means of transportation. All machinery is operated by purchased electric power.

The Beaver Valley Sand Co. operates a dredge in Beaver River at West Ellwood Junction. The product is washed building and concrete sand and gravel.

The Ellwood Stone Company makes sand at its quarry near Koppel by crushing the spalls. The rock is ground in a wet pan and the sand is cleaned in three screw washers. The product, a white silica sand, is sold mostly for traction sand.

PLATE XV

A. Sand and gravel pit of Mahoning Valley Sand Co., 1½ miles south of West Pittsburgh.



B. Oil well and bell hanger pump near Bessemer.

SANDSTONE.

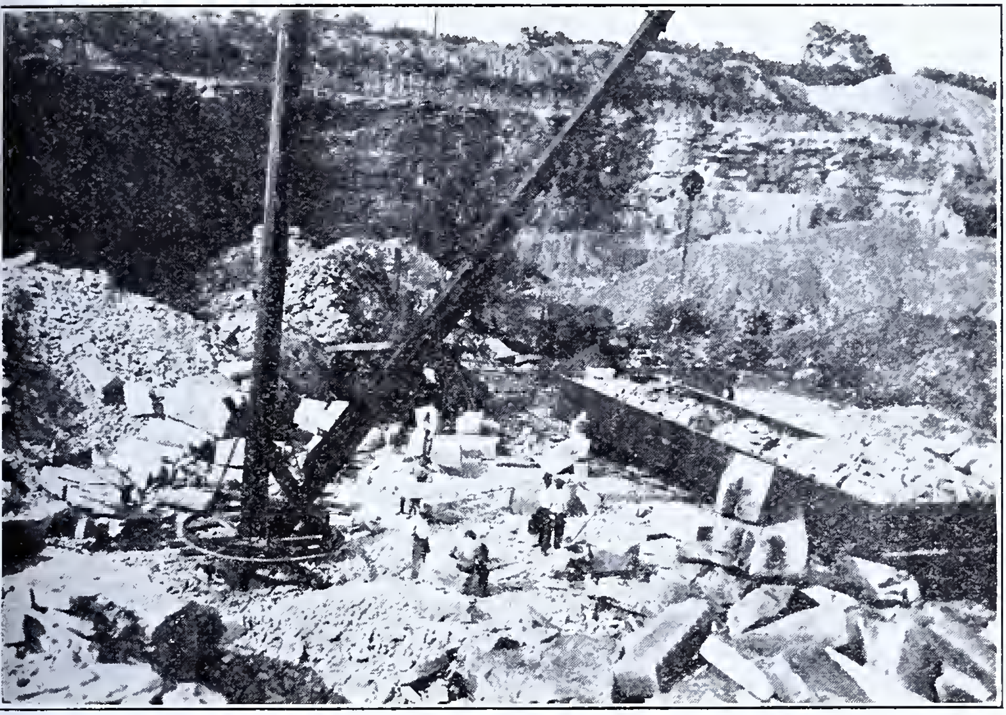
Sandstone has been quarried for building purposes at many places along the Beaver Valley, as shown by the map, Plate IV. Most of the quarries are in the Homewood sandstone at the top of the Pottsville series. A few have produced stone from other horizons, as the John Boyer quarry (now long abandoned) in the Butler sandstone at Beaver Falls. Large quantities of excellent stone are readily available but the use of concrete in construction has greatly reduced the demand for this stone.

In 1926 only two sandstone quarries were in operation in this quadrangle. Ellwood Stone Company, Ellwood City, D. J. Jones, manager, was organized in 1901 and incorporated in 1909. This company began quarrying a 40-foot ledge of massive Homewood sandstone on the south bank of Connoquenessing Creek at the west end of Ellwood City, and has operated continuously. For 10 years the product was 200 cars of 20 yards each, and for 4 years 400 cars. It is estimated that the total output has been about 140,000 cubic yards of stone. Much of the product has been large blocks for bridges and and other masonry. The Grant Street bridge at New Castle, the P. & L. E. R. R. bridge at Beaver, about 20 bridges in Allegheny County, and many of the piers of the Market Street bridge across the Susquehanna River at Harrisburg are built of the stone quarried by this company. Quarrying has progressed down the creek and the present operation is on the east bank of Beaver River opposite Hoytdale. Blocks up to 6 feet long are quarried and rough dressed by hand with a force of 20 men.

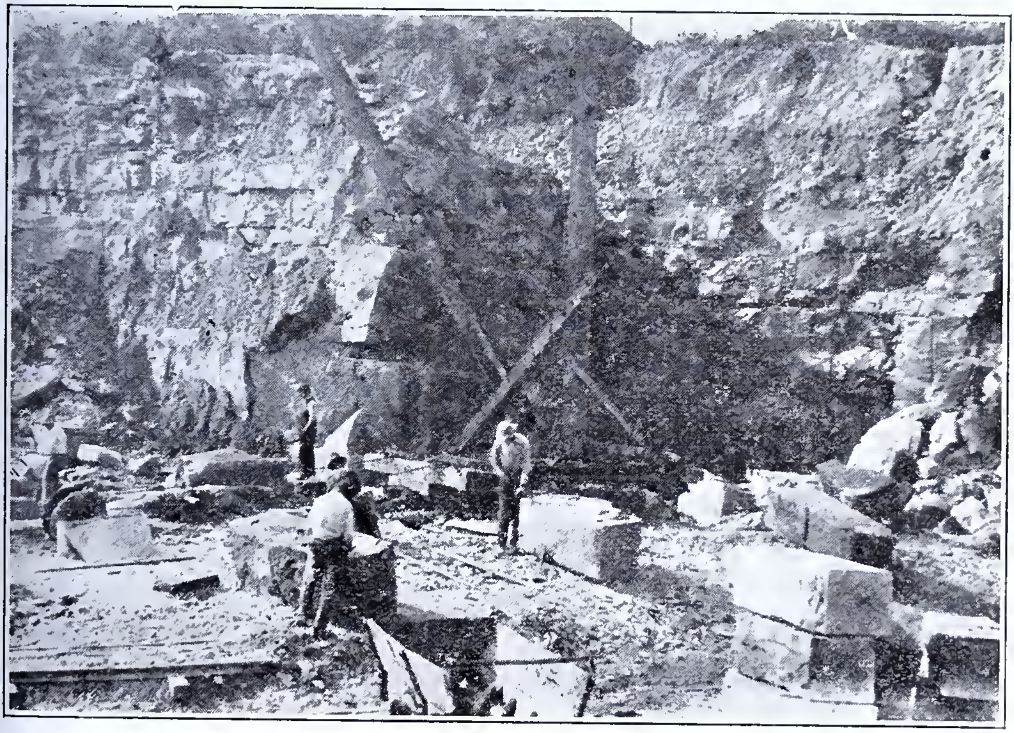
This company operates a large sandstone quarry at Koppel on the west bank of Beaver River about 1 mile farther down stream, on the Pittsburgh & Lake Erie Railroad. This quarry was formerly operated by the Clydesdale Stone Company, but was acquired by the Ellwood Stone Company in 1922. It is on the same general ledge, the Homewood or Beaver Valley sandstone. This quarry has a face about 1,000 feet long, and 40 feet high, and employs 80 men. The former company quarried stone here for the famous mile-long stone arch bridge of the Pennsylvania Railroad at Rockville near Harrisburg, for the Pennsylvania Railroad piers at Havre de Grace, Maryland, for the Panhandle Railroad bridge at Chicago, the B & O. R. R. elevated approach at Washington, D. C., and for the Henry Ford home at Dearborn, Michigan.

The stone in these quarries is gray to light cream color, medium grain, massive sandstone admirably adapted to heavy masonry. It works readily when freshly quarried and the surface hardens or indurates on exposure. The ledge in this vicinity is about 40 feet thick and the lower part in some quarries is more massive than the

PLATE XVI



A. Sandstone quarry of Ellwood Stone Co., Koppel.



B. Detail of sandstone beds in picture above.

upper. The sandstone takes its name from the hamlet of Homewood, 4 miles north of Beaver Falls, "where it appears in one solid unbroken ledge 155 feet thick."

Quarries of the Ellwood Stone Company are shown in plate XVI. The stone is broken out by drilling with compressed air tripod drill, and light blasting. Loosened blocks are lifted out by a long wooden boom derrick operated by steam power, and dressed by hand to dimension on the quarry floor. The same derrick may load the finished block into a railroad car.

PETROLEUM AND NATURAL GAS.

As shown by maps of the oil and gas fields this area lies in the great oil and gas belt which extends in a southwesterly direction from southern New York to West Virginia. Drilling has been done intermittently since 1859 or 1860 and about 1,500 wells are known to have been drilled. Both oil and gas have been produced locally in commercial quantities, but the area has not consistently yielded large or long-lived gas wells, though some of the oil wells are very long-lived and small. The following observations on the occurrence and distribution of the oil and gas should be read with reference to accompanying maps and tables.

Geologic Occurrence.

It has long been known that pores and cavities of certain rock strata may contain oil and gas sufficiently accumulated in favorable localities to yield their wealth to the drill. There are two chief theories regarding the natural origin of these substances, one holding that chemical decomposition of inorganic minerals has been the source, and another, more generally deemed probable, that the alteration of plant or animal remains in the sedimentary strata has yielded these hydrocarbons. The question of origin remains unsettled in the minds of scientists but certain facts of distribution of oil and gas have been gradually established and seem, within limits, to be helpful. The "anticlinal theory" as formulated and applied by I. C. White, Edward Orton, John F. Carll, and other geologists has the general though not unanimous support of scientific investigators and intelligent operators. The theory may be explained as follows: Where gas, oil, and water occur in an inclined porous rock stratum they have a tendency to arrange themselves in the order of specific gravities, gas at the top, oil in the middle, and water at the bottom. If rocks are folded and the critical stratum is completely saturated with these substances the gas will be found along the crests of anticlines, the water in the synclines, and the oil on the intermediate flanks provided the crests of the folds are horizonal.

if the axes of the folds rise or fall along their courses the gas will be found in the highest structural situation and the oil and water, in order, below it. If the producing stratum is only partially saturated then oil contained above the water line will tend to descend through force of gravity until the saturation line is reached and any oil below this line will tend to rise to it. Oil, therefore, will be found floating on the water either on anticlines or synclines according to the height of the line of saturation. Gas, as before, will be above the line and migrate to the highest structual position. According to this theory it becomes important to determine whether an unproductive well finds water in the oil sand. If it does then further tests should be made structually higher, but if the sand is free from water then the chances will be better to locate at some distance in the direction of dip of the rocks. Modification of the above rule must be expected if the natural arrangement of the fluids is prevented by variations in porosity of the producing sand, or by friction due to lack of adequate dip. It has been pointed out by Griswold[1] that flats or terraces in dipping sands are especially favorable for oil accumulation.

The laws governing the distribution of oil and gas must be sought by studying the relations of the strata to one another and to the structure of the region. Most of the information must be obtained from well logs, usually imperfect, and including errors of identification and of measurement. The following notes on the productive sands and their relation to structure are based on incomplete data but are presented in the hope that they will at least in part describe the true relations and prove of value.

The known vertical and horizontal distribution of oil and gas in this area and their relation to the anticlinal theory are described in the following sections.

DESCRIPTION OF DRILLER'S "SANDS."

Forty-foot sand (Homewood).

The top sandstone shown in a number of the accompanying sections, Plate X, is known to drillers as the Forty-foot from its thickness. It outcrops along the Beaver Valley as a massive quarry rock but elsewhere changes, locally, to shale. Logs from the Big Meadows gas field east of New Castle and also from Wurtemburg show this sandstone in its usual relations, about 140 to 160 feet below the Middle Kittanning coal or 60 to 80 feet below the Vanport limestone. The Homewood varies greatly in thickness, color, and texture as more fully described on previous pages.

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[1] U. S. Geol. Survey Bull. 318, p. 16, 1907.

Sixty-foot sand (Upper Connoquenessing).

A thick sand known as the Sixty-foot lies a few feet below the Forty-foot and separated from it by a thin zone of shale, limestone, and coal. This bed outcrops along Connoquenessing Creek and elsewhere. It is commonly recorded in logs of deep wells as a thick sand of medium to coarse texture and light-gray color.

Big Injun or Mountain sand (Lower Connoquenessing).

The name Big Injun, or Mountain, is applied by drillers of the region to a massive, water-bearing sand with its top 200 to 300 feet below the Middle Kittanning coal and its base 300 to 400 feet above the Berea. As pointed out on page 61 the true Big Injun of the Pocono group is probably absent from this region and the name, in many cases, is erroneously applied to younger rocks of Pottsville age which here are unusually well developed and lie about the same distance above the Berea as does the true Big Injun in adjoining areas. The name as used here refers locally to a single bed 70 to 125 feet thick or again to one or more of several sands which are separated by shale "breaks." The Big Injun in the Purdy pool, near the center of Darlington Township, is the highest producing sand of the quadrangle. Its base is not reached in many wells, since it is water-bearing, and its thickness is only known to be usually in excess of 45 feet. It varies greatly is character, having a top shelly portion in several wells, and being entirely absent in two or more wells at the south end of the field. Comparison of the log of Bradford No. 1 well, No. 23, Plate X, with other sections indicates that this sand probably lies at the horizon of the Lower Connoquenessing sandstone. The distance below the Middle Kittanning coal recorded in the several wells varies from 225 to 315 feet, in part because of the change in texture of the upper portion of the bed. It is separated from the Berea by 300 to 350 feet of strata. In other logs plotted on the accompanying sheet the sand identified by the driller as Big Injun or Mountain is in some cases Connoquesessing, in others possibly Sharon, or still again, Slippery Rock. Carll found that the First Mountain sand in Butler County is equivalent to the Connoquenessing sandstone.[1]

Slippery Rock sand (Shenango ?, Sharon ?).

The Slippery Rock sand was the producer in the seventies along Slippery Rock Creek, northeast of Wurtemburg. Drillers apply the name to two sands separated by a thin shale "break," the upper stratum known as the Oil sand and the lower as the Salt sand, each about 35 feet thick. As shown by the accompanying sections, Plate

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[1] Pennsylvania Second Geol. Survey, Rept. III, p. 82.

X, the top of the upper members lies about 375 feet below the base of the Vanport limestone or, as White says, "240 feet below the Lower Mercer limestone,"[2] This sand lies below the horizon of the Sharon coal in the zone which may be Pottsville or Pocono as explained on page 60. It was regarded by Carll as equivalent to Sharon or to the Second Mountain sand of Butler County.[3] White, however, considered it as Pocono. Possibly it represents the Big Injun of Butler County, though thinner and lower here than in that region.

Berea sand (Amber, Smiths Ferry).

The term Berea is extensively applied to a sand in various fields of the quadrangle and is considered identical with the sand at Berea, Ohio. The question of correlation is discussed on another page. It lies 675 to 740 feet below the Middle Kittanning coal or about 630 feet below the Vanport limestone, and is usually reported to be 30 or 40 feet thick. It is a light-gray to white quartzose rock of fine, even texture though locally reported pebbly; as in Economy well No. 3 at Beaver Falls. The sand is exceptionally reported absent or, again, may be continuous with the next lower sand from which it is usually separated by a shale "break." The Berea is the oil-producing sand at Beaver Falls, New Galilee, Bessemer, and scattering points and is equivalent to the Smiths Ferry sand of the southwestern area and to the Amber sand at Ellwood City and vicinity. The sand is locally either saturated with water or practically free from it. Pay streaks occur from 8 to 28 feet in the sand, commonly at about 20 feet. The Berea locally produces gas; as in the wells in western Chippewa Township.

Gas sand.

The sand below the Berea is known as the Gas sand and is regarded by some drillers as equivalent to the Butler County or Murrysville sand. Its top lies 40 to 90 feet below the top of the Berea according to the thickness of the latter and of the "break" which usually occupies 5 to 40 feet between the two sands. The Gas sand is commonly 75 to 100 feet thick but locally diminishes to as little as 35 feet. Gas is encountered from 1 to 25 feet below the top; usually within 5 feet. It has a rock pressure of 150 to 200 pounds in South Beaver Township and in Slippery Rock Township. In the latter area many of the wells ran 165 pounds rock pressure and 150 pounds or more the first minute in 2-inch tubing. Immediately below the gas the sand is very wet and a well that is drilled into this is short lived.

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[1] Pennsylvania Second Geol. Survey, Rept. III, p. 82.
[2] Pennsylvania Second Geol. Survey, Vol. QQ, p. 88.
[3] Pennsylvania Second Geol. Survey, Rept. VII, p. 82, Rept. 15, p. 126.

Lower sands.

Among the lower sands penetrated in the quadrangle only one has been commercially productive, the so-called Thirty-foot of the Ellwood City area. It lies about 430 feet below the top of the Berea or Amber sand and measures 25 to 50 feet thick. The wells in the vicinity of Wurtemburg and Frisco were strong producers, but no reliable records of pressures are obtainable.

A few logs report the Hundred-foot sand or "shells" about 200 feet below the top of the Berea, and immediately beneath the first notable red shale. There is no reliable report of any commercial production from this or the other deep "shells" or sands.

GAS FIELDS.

Big Meadows. The Big Meadows field lies in the northeast corner of the quadrangle about five miles from New Castle and just north of Energy. The map, Plate V, and tables show about 20 wells here, in Shenango and Slippery Rock townships, and doubtless a few were overlooked. This field was struck in the early 90s, many of the wells gaging 75 to 140 pounds per minute in 2-inch tubing, and 150 pounds rock pressure. The Big Meadows Gas Company, and later the New Castle Light and Heat Company controlled the field and piped the gas to New Castle for use at the iron and steel works and other factories. There is now no commercial production here. The gas was reached from 750 to 900 feet below the surface, and from 730 to 760 feet below the top of the Vanport limestone, presumably in the same Gas sand as in the Brush Run field. This area is structurally the highest of the quadrangle, and has been the collecting place for the gas of the beds which rise on the flanks of the anticline. The structure is an irregular dome, with the highest place east of the quadrangle edge. The altitude of the gas pay varied from 415 to 460 feet; the lowest being in the southwest corner of the area and the highest along the east margin.

Ellwood City. A small reservoir of gas in the Gas sand was struck northwest of Ellwood City by six or more wells of the Manufacturers Light and Heat Company. No data are available regarding production or depth. The field does not appear to be limited by dry holes on the west, though this may be due to lack of information. The general structure here would seem to favor the wells at the north and northeast part of the area.

Squaw Run. Eight or more wells near the mouth of Squaw Run produced gas from the Gas sand at an altitude of about 300 feet but little information is available about them. Shows of oil are reported in the Slippery Rock and the Berea sands. The Ellwood Gas Company and the Manufacturers Light and Heat Company owned most of the wells; and H. N. Dambach, one or more. In well No. 560 on the Mehard farm, water is reported in the sand under the gas.

Wurtemburg-Frisco. A small field of gas in the so-called Thirty-foot sand was struck at Wurtemburg at a depth of about 930 feet and about 430 feet below the top of the Berea. Eight or more wells were drilled by the Manufacturers Light and Heat Company. East of Frisco four wells owned by Finnegan, Slater, and Ryan produced strong flows of gas from the same sand.

Brush Run. The Ohio Valley Gas Company and Bridgewater Gas Company opened the Brush Run field in the Gas sand, drilling a dozen or more producers in the winter of 1897-98. The wells are said to have been poorly handled and were drowned out after about 18 months. Later the Manufacturers Light and Heat Company drilled successfully in the same territory, getting wells with 90 pounds or more pressure in 2-inch pipe the first minute, and 110 pounds rock pressure. One of the old wells is said to have shown 182 pounds rock pressure. This gas horizon lies across the top of an anticline shown by contours on the Middle Kittanning coal, and ranges from 240 to 280 feet in altitude, lying highest at the edge of the quadrangle. The general structure would seem to favor an extension of the field to the east and northeast. Both the Gas sand and Berea sand show gas in this area.

College Hill-Beaver Falls. Gas has been found at Beaver Falls with indifferent success during three periods of excitement. Notes on the early development have largely been obtained from Mr. James Patterson of Beaver Falls, to whom the writer acknowledges his obligation. As early as 1859 the well at Eastvale, No. 222, was drilled to salt water and obtained a little oil and gas in the Berea sand. Shortly afterward, one in Beaver Falls at the foot of Third Street was drilled to the Berea and later to the Gas sand by the Economite Society. A show of heavy oil is reported from the Big Injun and a little gas in the Berea. Gas from the Gas sand was used in local factories. A later well at the mouth of Bennett Run stopped with a show of oil and gas in the Berea. About 1865 two wells put down in "Boyle's Basin," north of the Fetterman bridge, showed oil and gas but were not piped to town. Similar results are reported at the old waterworks, near Geneva College. None of these wells was shot. A good gaser which threw water 100 feet above the ground was drilled to the Gas sand at the Inghram-Richardson enamel works. The Co-operative Flint Glass works at the foot of 16th Street also obtained gas from the Gas sand. About 1877, gas wells were drilled and utilized in the south end of town, at the saw factory, shovel works, and cutlery works. The Economy No. 3 well furnished more gas than could be used by the cutlery works, at a pressure of 15 to 20 pounds. The sand contained pebbles as large as a hazelnut, and yielded salt water.[1] A dry well 1800 feet deep was put down in 1885-86 on the James Clayton place in White Township near Beaver Falls. During a renewal of drilling about 1892 or 1893, gas wells were brought in from the Gas sand at the Keystone Driller Company's plant, the Book House, and Geneva College. East of the river, a well on the Blinn farm made a good showing of oil in the Berea but was drowned in the Gas sand. A well of the Anderton Brewery Company produced from the Gas sand for a time.

Mount Jackson. Within two miles of Mount Jackson about 40 wells have been drilled, over 20 of which are reported as gas producers. The gas is obtained from the Gas sand at a depth of 560 feet, perhaps between the Berea and Hunderd-foot sands. The wells are said to produce much water and the gas is used only as reserve for emergencies. The rock pressure was 100 pounds in 1904, 185 pounds in 1910, and 162 pounds in 1919.

OIL POOLS.

Harbison Hollow pool. The pool in Harbison Hollow, west of College Boro, has produced the most oil in the south part of the quadrangle, and includes some 40 wells mentioned in the following tables. Most of these were drilled in the fall of 1904 to the Berea sand at a depth of about 600 feet below the valley bottom or 300 feet above sea level. The sand is of fine, even texture and light-gray color. The best well, No. , Pl. V, was Gailey, Figley and Ferguson's No. 3 on the T. H. and J. R. Boyd lease, which made 55 barrels of oil and 1 barrel of water daily. A number of others made 20 barrels of oil or better, with the water up to 10 barrels. From this, production dwindled to 5 or even 1 barrel of oil with large quantities of water. The wells ran down rapidly, and after a year many were abandoned and the production of all remaining was under 50 barrels. The short life of the wells is thought by operators to be related to the shallow depth to the pay streak which here is 15 to 20 feet below the top of the sand. The Berea is 690 to 710 feet below the Middle Kittanning coal, which lies 25 feet above the bed worked here at Boyd's mine. Apparently there is a terrace-like flattening in the structure at this place and this coincides with the line of water saturation of the sand. Oil from the south and east may have risen through the water-laden sand to this area and on the other hand, that from the northwest has drained from the higher dry slopes of the Homewood anticline. The pool has been limited by dry holes on practically every side. One well, was drilled by the Keystone Driller Company to a depth of about 2,000 feet, but found no sands below the Gas sand. A few gas wells here produce from the Gas sand.

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[1] Pennsylvania Second Geol. Survey, Rept. Q, p. 207.

New Galilee pool. West of New Galilee, some 15 wells drilled in 1904 proved productive. The pool has since been extended to the south. The Berea is reached about 600 feet below creek level or about 330 feet above sea level. The sand is so wet that 10 to 20 barrels of water is pumped before any oil is obtained. One well came in at 7 but settled to 3½ barrels, and in general the output has been 2½ to 5 barrels. The first pay lies 10 to 15 feet below the top of the sand, and a second pay 30 feet below the top. Since the altitude of the sand is nearly the same in these wells, varying from 335 at the south end to 325 at the north this pool and the outlying wells near by indicate a sub-level sand over a considerable area. This gentle structure above more steeply dipping areas is a strong factor for oil concentration, though many unproductive spots may exist. The structure contours on the Middle Kittanning coal indicate that the underlying formations are in a gentle but irregular trough, the axis of which is through New Galilee and Chewton and rises to the northeast. Drilling along the axis in this direction might enable one to tap the sand at or just above the line of saturation, and hence get oil with less water.

Madden Run pool. A half dozen wells on the M. K. McGeorge farm west of the New Galilee pool, produce from the Berea at a depth of about 650 feet, or 320 feet altitude. The sand is very wet and has conditions like those in the area to the east, from which it probably is not separated structurally. The wells pump from 1 to 5 barrels of oil each, daily, and considerably more water. On prolonged pumping one of the wells produced gas. Extension of the field to get above the water, would probably be to the north, but the sand has nearly the same level 2 miles due north in well No. 237.

Purdy pool. The Purdy pool, northwest of Darlington, produces from the Lower Connoquenessing sandstone, here called the Big Injun. Some half dozen wells yield from 1 to 6 barrels each. They came in with 5 to 15 barrels. The largest well had an initial daily production of 65 barrels. The sand lies 225 to 315 feet below the Middle Kittanning coal, 300 to 350 feet above the Berea, and 450 to 475 feet below the upland. It is more than 40 feet thick, but wet at the bottom and hence not drilled through. The sand varies from massive to shelly within short distances, and well No. 183 at the south end found only shale at this horizon. The first pay, 4 to 15 feet in the sand, lies nearly level at 655 to 710 feet altitude; and the second lies some 40 feet lower.

Elder pool. Southwest of Darlington 1½ miles on the old Fergus Johnson farm, now the Elder place, a 2,440-foot well was drilled in 1886. A little oil was found in the Berea and Hundred-foot and shows of gas at several horizons. Later, about 1901, five other wells were drilled to the Berea, at a depth of about 610 feet, and produced 2 to 4 barrels daily by pumping and settling off the water. The pool lies along the axis of the Darlington syncline, which rises northward, and the sand is 270 feet above sea level. This is 50 feet or more lower than at the New Galilee pool, and the oil would be expected to rise to the higher area, if the sand is porous. The L. Boston hole west of Darlington, No. 133, found the Berea sand free from water, thus indicating a barrier here to the upward movement. An extension of the Elder pool on present evidence would be most likely to the northeast towards No. 133.

Bessemer pool. Oil was discovered in the Berea sand at Bessemer in 1906 by Mr. J. A. Weber, and in the 20 years since that date between 1,000 and 1,500 wells have been drilled in this pool within 2 miles of Bessemer. The depth to the sand is 600 to 800 feet, and the sand is 30 to 40 feet thick. It has been a very successful pool for, according to reports, 95 per cent of the wells produced oil. One company reports that of 316 wells drilled, 310 produced oil. The geologic structure seems to be nearly flat and the oil equally distributed so that wells anywhere in a radius of 2 miles from the village have been productive. All of the wells have been small producers, starting even in the early days with only 1 to 5 barrels. The average daily production per well in 1926 was about 3 gallons; some wells, however, were not producing more than 1 gallon per day. With approximately 800 producing wells in this pool the daily output in 1926 probably was not over 30 barrels. Although the wells are small producers they are long lived. It is not ususual for wells to be pumped for 10 to 15 years, and the original well drilled in 1906 was still pumping 20 years later.

Two companies are now operating in this pool, the Premium Oil Company of Bessemer and the Crew-Levick Company of Pittsburgh. The wells are pumped in gangs, a single gasoline engine pumping 8 to 10 wells at a time. The pump rod in each well has a bell crank operated by a light cable or rods. Oil is shipped from Bessemer by tank car to Oil City and Titusville for refining.

RELATION OF OIL AND GAS TO STRUCTURE.

Possible extensions. Reference has already been made to the anticlinal theory of oil and gas accumulation as developed by other investigators. The important considerations are the structural folds, the porosity of the rock, and the degree of its saturation with salt water. Since the theory may be used in the further development of the industry in the New Castle quadrangle a test of its application should be made in the case of the Gas sand and Berea sand.

Gas sand. The Gas sand lies in long, low waves, and commonly is 750 to 785 feet below the Middle Kittanning coal. While this variation of interval renders the structure contours based on the coal only generally representative of the structure of the sand, nevertheless the relation of gas accumulation to rock folds as shown by these contours may be studied.

So far as reliable evidence goes the sand is saturated with salt water except for the pay streaks; therefore, according to theory, the gas should be found on the crests of anticlines and domes. This in large measure seems true. The Big Meadows field lying on the broad top of a dome saturated with water has been the collecting place for the gas from the sloping sides. The altitude of the sand where penetrated by productive wells ranges from 415 to 460 feet. The Brush Run field lies at or near the top of a spur of the Homewood anticline and its extension is represented by many wells to the northeast along this fold. The sand rises from an altitude of 240 to 280 feet along Brush Run and to 315 feet, southwest of Morado. The Beaver Falls gas production occurs above the middle of the east flank of the Homewood anticline where the elevation of the sand above sea varies from 115 to 225 feet. The dry holes between producing wells suggest that the sand is unequally porous, but as the surface beds rise rapidly to the north from Beaver Falls and flatten near the north end of the field, possibly this is the location of a small anticline in the Gas sand. The productive sand in the Squaw Run field lies at 280 to 300 feet altitude and is near the top of the Homewood anticline, as is also the field north of Ellwood City farther west.

While the productive Gas sand thus rises from 115 feet in the south part of Beaver Falls to 450 feet in the Big Meadows field, practically all the gas fields and also the scattered producers of gas lie at or near the tops of anticlines.

Berea sand. The Berea sand is not perfectly parallel to the Middle Kittanning coal, as shown by the difference of interval between the two beds at several places; along Brush Run at well No. 500, and near the mouth of Connoquenessing Creek, at No. 547, the interval is 720 feet; at Harbison Hollow it is 705 feet; along Jordan Run at well No. 31 it is 695; along Madden Run at No. 179 it has decreased to 685 feet. The diminution appears from these figures to be towards the west, but other data make this general conclusion unwarranted. Since the variation but slightly exceeds the contour intervals used to show the lie of the coal, the Berea structure is approximately indicated by the same contours.

The degree of saturation of the Berea sand cannot be stated positively. Information is sadly lacking although special inquiry was made. At the biggest pools the oil is pumped with much water. At Harbison Hollow the altitude of the sand in the producing wells is 310 to 325 feet. Since below this range excessive water is pumped and above it only a showing of gas is obtained a local water line is thus indicated. The production from the New Galilee and Madden Run pools is similarly obtained where the altitude of the Berea is 310 to 335 feet. A well to the south, No. 145, and others not mapped have a light production a little below this limit. So far as known those wells striking the sand above 335 feet are not producers, and in the case of No. 176 but little water was found in the sand, which here lies 340 feet above sea. The other unproductive wells around the pools offer no information about either the water or gas. If lack of oil is accompanied by lack of water, the local line of saturation is seen to agree with that at Harbison Hollow, and in both cases, theoretically, the oil has drained from the higher slopes to the water-logged sand. The water itself is held in the present pools by unequal porosity, or friction, in the sub-level sand, or by artesian head which is effective to an altitude of 325 to 340 feet.

But water and oil occur both higher and lower, structurally, than this local saturation line. Along Mahoning River oil and water were obtained from the Berea at 450 feet altitude; and also northeast of Ellwood City wells striking the sand at 370 feet altitude show oil. On the other hand in the Elder pool below Darlington the producing sand has a height of only 270 feet.

The study of water in the Berea sand may be extended favorably to the Beaver, Steubenville, and Cadiz quadrangles to the south and west, which have been described. In the Cadiz quadrangle the saturation line is 280 feet below sea level.[1] Eastward, in the Steubenville quadrangle it is about 30 feet higher. In the Beaver quadrangle while proof is not positive, a controlling water line is considered probable;[2] but in the Hookstown and Fairview pools the altitude of the Berea varies from 35 to 200 feet above sea level. Returning to the New Castle area a water line of some significance occurs at 310 to 335 feet, but along Mahoning River the sand is wet as high as 450 feet. From this Mahoning area to the Cadiz quadrangle the Berea dips 730 feet with no barrier folds sufficiently high to prevent the water from settling to the lowest area; yet this drainage has not been accomplished.

In the areas reviewed water lines are thought to be important factors in determining the position of productive pools. It appears, however, that no uniform line of saturation occurs in this basin and that this factor is of strictly local importance. Such pools as occur above the local lines are probably due to friction on terraces or to local non-porous barriers.

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[1] U. S. Geol. Survey Bull. 318, p. 33.
[2] U. S. Geol. Survey Bull. 286, p. 82.

Conclusion. Accumulations of gas in the New Castle quadrangle occur mostly along the tops of anticlinal folds and domes, and experience both here and elsewhere makes it strongly probable that any further prospecting for gas will be best rewarded by selecting locations along these structural features.

Oil pools in the Berea sand of this and adjoining quadrangles occur variously but chiefly in three general relations; at the water line in areas of partly saturated sand; above the water line along structural flats or terraces; above the water line on the slopes of anticlines as determined by barriers of non-porous rock. While the prime object of this work has not been to discover new oil pools, and the limitations imposed by the data are great, certain suggestions may not be amiss.

Further drilling to the Berea may be productive any place but certain areas seem most favorable. Within the zone of the apparent 325 to 340-foot water line as described, the present pools may be extended despite holes reported dry, and the effort should be to move up the dip of the rocks a little so as to get above the main body of water. Thus the area northeast of the New Galilee pool appears promising, since the Berea is nearly flat and oil reported in wells No. 582 and 547 suggests that local pools may be found along this broad synclinal trough. As the area west and north of the Madden Run pool may contain others, accurate reports about the condition of the sand and its contained water in certain holes around Enon Valley would be helpful. While the presence of oil in the Berea sand in the New Galilee pool at the same altitude as in the Harbison Hollow pools may be mere coincidence, it suggests the influence of a continuous line of saturation. If it actually exists, then where the sand is porous, water and oil should occur along a sinuous belt from New Galilee, passing east of Darlington and crossing Brush Run near wells No. 506 and 507; thence swinging eastward in a flat curve south of the quadrangle and reentering it in the vicinity of the Wilson wells, No. 56 and 57. In like manner, in the area northeast of Harbison Hollow, if the sand is porous the belt of oil and water might be expected in the vicinity of the 1025 foot coal contour as it swings east of Thompson Run mine and loops back near North Sewickley. Along this outlined course are found some producing wells near Darlington, as Nos. 16, 17, and 18; some showing oil; some gas; and some reported dry. South of the quadrangle Woolsey has shown the position of several holes north of McElroy Run and of South Branch of Brady Run. His data do not indicate whether these wells showed oil or water or open sand. Similarly nothing could be learned of the porosity or saturation of the Berea sand in wells northeast of Harbison Hollow. Some of them were drilled long ago and perhaps under present day standards might be regarded as productive. In the recently drilled well on the Walker farm, No. 436, the altitude of the Berea is 337 feet but the record is not complete. The North Sewickley syncline, which has been tested only by a shallow unfinished well, No. 435, may contain oil.

Several structural flats or terraces are worth mention. That east of North Sewickley unless absolutely condemned by well No. 225, of which little is known, appears to be favorable. Another terrace occurs west and a little south of Moravia; and another from about two miles northwest of this town to Mt. Jackson. The structural trough southwest of New Castle along Beaver River is situated so as to drain higher areas both to the east and west and should contain favorable areas for prospecting along its flanks or its bottom, depending on the conditions of rock saturation and porosity.

As already explained, the accompanying map, though imperfect, may be useful in planning further drilling. It indicates the approximate "lie" of the Berea and other strata by its structure contours on the Middle Kittanning coal, and thus suggests the direction in which present pools can most likely be extended at the same structural level, or the direction to move in order to go up or down the dip in search of a line of saturation. Knowledge of the position and elevation of bench marks will enable the operator to calculate the approximate depth to the oil and gas sand at any location and to water horizons which may need casing off. Thus, having selected a location for drilling, the altitude of the well mouth may be determined either approximately from the contours of the topographic map, or exactly by a spirit level line from the nearest bench mark. To calculate the depth to a sand, as for example the Berea, determine first, the altitude of the Middle Kittanning coal from the structure contours nearest the proposed well; second, determine the altitude of the Berea by subtracting from this figure, 710 feet as the average interval between the coal and the Berea, or use a closer value if known from closely adjoining wells. The desired depth to the sand is then obtained by subtracting the altitude of the Berea from that of the well mouth.

Partial List of Wells in or near the Newcastle Quadrangle Arranged Alphabetically by Townships and Boroughs, and in order of Map Numbers.

BEAVER FALLS BOROUGH

1. Economy No. 2
2. Cutlery Works
3. Mayer Pottery Co.
4. Keystone
5. Anderton Brewing Co.
6. Merriman lot
7. McCormick lot, No. 1

BIG BEAVER TOWNSHIP
(Beaver County)

12. Dunn, Hugh
13. Serfoss
14. Creese, S. S.
15. Johnson, Washington
16. McMahon, Alex.
17. McMahon, Alex.
18. McMahon, Alex.
19. Fossnut (?)
20. Johnson, Washington
21. Emery
22. Beaver Clay Mfg. Co.
23. Ray, Jennie
24. Foster Heirs
25. Hunter, Webster
26. Reed, Samuel
27. Clydesdale Stone Co.
28. McKim, No. 2
29. McKim, William
30. Whan No. 1
31. Mitchell, John
32. Short, Enos
33. McClure, W. J.
34. Dillen, L. D. No. 1
35. Young, William
36. Patterson, James
37. Dillen, L. D.
38. McChesney, W. T.
39. McClure, W. J. No. 1
40. McClure, W. J.
41. McClure, W. J.
42. Price, E. C. No. 2
43. Price, E. C. No. 1
961. Unknown
962. Unknown

BIG BEAVER TOWNSHIP
(Lawrence Co.)

48. McChesney, W. T.
49. Wampum Run
50. Wampum lot (?)
51. Weitz
982. Unknown
983. Unknown
984. Unknown
985. McAnlis
986. McAnlis (?)
987. Unknown
988. Unknown
989. Unknown
990. Unknown
991. Unknown

CHIPPEWA TOWNSHIP

55. Rhodes, R. M.
56. Wilson, Jefferson No. 1
57. Wilson, Jefferson
58. Blinn, Adam
59. Gilliland, David
60. Howley, M. P.
61. Craighead, Sarah
62. Grim Heirs
63. Edes, Samuel
64. Boyd, T. H.
65. Boyd, T. H. No. 2
66. Hassen, Caroline
67. Hassen, Caroline
68. Cunningham
69. Marlatt Heirs
70. Hassen, Caroline No. 1
71. Marx, E. T.
72. Wintergill, Robert and Ida
73. Salyard Heirs
74. Thompson, Anthony
75. Young, Albert No. 2
76. Young, Albert No. 1
77. Young, John
78. Dunlap Heirs
79. Logan, William
80. McLaughlin No. 1
81. Logan, Matthew No. 2
82. Fields, David
83. Naugle, No. 3
84. Naugle, No. 2

85. McClain, Elizabeth and Eva
86. Naugle, No. 1
87. McClain, John, No. 2
88. McClain, John, No. 1
89. McCarter, J. B. No. 2
90. McCarter, J. B. No. 1
91. Bogden, Simon, No. 1
92. Ferguson, Hugh, No. 1
93. Williams, No. 3
94. Williams, No. 1
95. McClain, John. No. 3
96. Ried, C. W., No. 1
97. McCaughtry, R. H. No. 1
98. McCaughtry, R. H. No. 2
99. McCarter, J. B. No. 3
100. Marshall
101. Riddle
102. Cunningham
103. Williams, No. 2
104. Hall
105. Ray
106. Kahle, P. L. No. 1
107. Kahle, P. L. No. 2
108. Hanna
726. McClain, J. M.
727. McClain, E. & E.
728. Unknown
729. Naugle, J. F.
730. McCarter, J. D.
731. McCarter, J. D.
732. McCarter, J. D.
733. Reid, C. W.
734. McCaughtry, M. J.
735. Unknown
736. Unknown
737. Penn-Beaver Oil & Gas Co.
738. Unknown
739. Unknown
740. Unknown
741. Cunningham, J. & S.
742. Hasson, M. C.
963. Boyd, T. H. No. 4

COLLEGE HILL BOROUGH

115. Reeves, No. 1
116. Economy (?)
117. McKnight
118. Boyle, John Nos. 1 & 2
119. Boyle, David, No. 1

DARLINGTON TOWNSHIP

125. Johnson, Fergus
126. Elder, Annie
127. Elder, M. J. No. 1
128. Elder, M. J. No. 2
129. Dawson, Edmund
130. Caughey W. J.
131. Caughey, James
132. O'Neill, H.
133. Boston, L.
134. Unknown
135. Unknown
136. Unknown
137. Patterson, No. 1
138. Patterson, No. 2
139. Unknown
141. Anderson Heirs, No. 1
142. Unknown
143. Unknown
144. Unknown
145. McMinn, W. S. No. 1
146. Hannah
147. Patterson
148. Unknown
149. Unknown
150. Unknown
151. Unknown
152. Unknown
153. Unknown
154. McClure, W. J. No. 1
155. McClure, W. J. No. 4
156. McClure, W. J. No. 2
157. McClure, W. J. No. 3
158. McGeorge, John, No. 2
159. McGeorge, John, No. 4
160. McGeorge, John, No. 3
161. McGeorge, John
162. McGeorge, John, No. 1
163. Price, E. C. No. 2
164. Price, E. C. No. 1
165. Price, E. C. No. 3
166. McGeorge, Mark, No. 1
167. Price, E. C. No. 1
168. McGeorge, Mark
169. McGeorge, Mark, No. 1
170. McGeorge, Mark
171. Greer, George, No. 2
172. Greer, George, No. 1
173. McGeorge, John, No. 5
174. McGeorge, Mark
175. McGeorge, Mark
176. Greer, George, No. 1
177. Greer, George, No. 3

178. Greer, George, No. 2
179. Greer, George, No. 4
180. McClure, John K., No. 2
181. McClure, John K., No. 1
182. Gibson, No. 1
183. Corrothers, No. 2
184. McCautry, No. 2
185. McClure, John K., No. 3
186. McCautry No. 3
187. McCautry No. 1
188. Gibson No. 2
189. Purdy, T. H. No. 5
190. Bradford Heirs No. 1
191. Rickert No. 1
192. Madden, James, No. 1
193. McClure, E. L.
194. McClure, E. L.
195. McClure, E. L. No. 1
196. McClure, E. L. No. 2
197. McClure, E. L.
198. McClure, E. L. No. 1
199. McClure, James, No. 1
201. Wefing
202. McGeorge, W. J. No. 1
203. McGeorge. W. J. No. 3
204. McGeorge, W. J. No. 2
205. McGeorge, W. J. No. 1
206. McGeorge, Priscilla, No. 2
207. McGeorge, Priscilla, No. 1
208. Boyd, W. C. No. 2
209. McGeorge, W. J. No. 4
210. Andrews, M. L.
211. Wilson
212. Zeh, John
964. Unknown

DAUGHERTY TOWNSHIP

220. Wilson, Addison

EASTVALE BOROUGH

221. Douglass-Whisler Brick Co.
222. Economy No. 3

FRANKLIN TOWNSHIP

225. McKim
226. Hazen, S. M.
227. Hazen, Pierce
228. Wilson, W. L.
229. Hazen, Pierce, No. 2
230. Keller

LITTLE BEAVER TOWNSHIP

235. Porter, Cyrus
236. Anthe
237. Prescott, John
238. Fox, A. D.
239. Riddle, O. I.
240. Fox, Walter
241. Rainey, R. A.
242. Rainey, R. A.
243. Rainey, R. A.
981. Taylor

MAHONING TOWNSHIP

244. Duff, Goodwillie
950. Williams, C. No. 5
951. Williams, C. No. 6
952. Davis, Robert
953. Davis, Robert No. 2
954. Davis, Robert No. 1
955. Davis, Robert
956. McComb, No. 1
957. McComb
958. McFate No. 1
959. McFate No. 6
960. McFate No. 5

NEW CASTLE BOROUGH

245. Shenango Iron Co.

NORTH BEAVER TOWNSHIP

250. McCalla
251. Reed, James E.
252. Hope, Robert
253. Patterson, Wm. No. 1
254. Chambers, Chas.
255. Chambers, Chas. No. 1
256. Kyle, John
257. Chambers, Chas.
258. Loure, John
744. Tindall, Jas.
745. Unknown
746. Leslie, F. W.
747. Kyle, D. & N. M.
748. Hopper, W. C.
749. Hopper, W. C.
750. Coulter, S. M.
751. Unknown
752. Coulter, S. M.
753. Robinson, L. L.
754. Brewster, J. N.
755. Petrie, W. A.
756. Shaffer, Holland
757. McClellan, John
758. Unknown
759. Unknown
760. Unknown
761. Unknown

762. Unknown
763. Unknown
764. Unknown
765. Unknown
766. Unknown
767. Fullerton, Jas. N.
768. Chapin, E. W.
769. Nesbit, J. M.
770. Nesbitt, J. M.
771. Gibson, Robt.
772. Gibson, Robt.
773. Klamer, Jno. D.
774. Klamer, John
775. Knox, John
776. Knox, John
777. Nesbitt, J. M.
778. Davison, W. J.
779. Laughlin, J. H.
780. Thompson, J. W.
781. Ferree, Alvin H.
782. Clarke, Jean
783. Thompson, J. W.
784. Cunningham No. 4
785. Cunningham No. 3
786. Cunningham No. 1
787. Cox
788. Clark, R. S.
789. Hieber
790. Hieber No. 2
791. Fullerton No. 13
792. McCreary, No. 4
793. Patterson, E. T. No. 8
794. Unknown
795. Unknown
796. Wiley, Geo. B. No. 5
797. Wiley, Geo. B.
798. Patterson, E. T. No. 9
799. Sherer, Jos.
800. Unknown
801. Unknown
802. Unknown
803. Unknown
804. Unknown
805. Unknown
806. Unknown
807. Sherer, R. M. No. 8
808. Sherer, R. M. No. 9
809. Sherer, R. M. No. 10
810. Brown, S. M. No. 6
811. Brown, S. M. No. 4
812. Shafer, Elmer
813. Brown, S. M. No. 1
814. McClelland, C. W. No. 4
815. McClelland, C. W. No. 5
816. McClelland, C. W. No. 6
817. McClelland, C. W. No. 7
818. McClelland, E. C. No. 1
819. McClelland, E. C. No. 2
820. McClelland, E. C. No. 3
821. Beigth, David
822. McClelland, Harry
823. Peden, A. S.
824. Unknown
825. Heldman (?)
826. Emery
827. Emery
828. Emery No. 3
829. Emery No. 4
830. Fosnot, Scott
831. Mack, Chas. No. 1
832. McWilliams, Joseph
833. McWilliams, Joseph, No. 24
834. Heldman No. 5
835. Heldman No. 6
836. McWilliams, Joseph
837. McWilliams, Joseph
838. McWilliams, Joseph
839. McWilliams, Joseph
840. McWilliams, Joseph
841. McWilliams, Joseph
842. McWilliams, Joseph No. 9
843. McWilliams, Joseph No. 8
844. McWilliams, Joseph
845. McWilliams, Joseph
846. McWilliams, Joseph
847. Heldman No. 14
848. Heldman No. 15
849. Heldman No. 11
850. Heldman No. 10
851. Wiley, W. H. No. 9
852. Wiley, W. H. No. 14
853. Unknown
854. Carnick
855. Bessemer Limestone Co. Power (?)
856. Bessemer Limestone Co. Power (?)
857. Bessemer Limestone Co. Power 6 No. 7
858. Bessemer Limestone Co. Power 6 No. 6
859. Bessemer Limestone Co. Power 6 No. 2
860. Bessemer Limestone Co. Power 6 (No. 10 or 11)
861. Bessemer Limestone Co. Power 4 No. 5
862. Bessemer Limestone Co. Power 3 No. 3

863. Anderson, N. P.
864. Anderson, N. P.
865. Anderson, N. P. No. 1
866. Anderson, N. P.
867. Pittsburgh Crucible Steel Co. No. 41
868. Mayberry Heirs, No. 10
869. Mayberry Heirs
870. Mayberry Heirs No. 9
871. Mayberry Heirs No. 8
872. Mayberry, C. O.
873. Mayberry, C. O.
874. Mayberry, C. O.
875. Unknown
876. Nelson, Alfred No. 8
877. Nelson, Alfred No. 2
878. Smith, J. L. No. 9
879. Smith, J. L.
880. Pittsburgh Crucible Steel Co. No. 14
881. Pittsburgh Crucible Steel Co. No. 25
882. Pittsburgh Crucible Steel Co. No. 29
883. Pittsburgh Crucible Steel Co. No. 37
884. Edgar, J. No. 6
885. Edgar J. No. 5
886. Edgar, J. No. 4
887. McCord, Mary J.
888. Hoffmaster, A. M. No. 8
889. McCord, Dwight No. 3
890. McCord, Dwight No. 2
891. McCord. Dwight No. 1
892. Hoffmaster, A. M. No. 7
893. Hoffmaster, A. M. No. 5
894. Baird. John No. 4
895. Baird. John No. 5
896. Rodgers, Chas. No. 10
897. Sheets, Robt., No. 1
898. Crum, Emery No. 8
899. Crum, Emery No. 7
900. Crum, Emery No. 10
901. Crum, Emery No. 18
902. Hayes, John No. 16
903. Hayes, John No. 17
904. Hayes, John No. 13
905. Hayes, John No. 3
906. Hayes, S. B. No. 8
907. Crum, Emery No. 2
908. Crum, Emery No. 15
909. Myers Combination
910. Myers Combination
911. Hayes, Clark No. 2
912. Hayes, Clark No. 3
913. Hayes, Clark No. 4
914. Hayes, Clark No. 5
915. Stanley, No. 3
916. Stanley, No. 2
917. Eckman, Boyd No. 8
918. Shingledecker
919. Shingledecker No. 6
920. Shingledecker, No. 7
921. Eckman, Boyd No. 5
922. Eckman, Boyd No. 9
923. Craycraft No. 1
924. Craycraft No. 2
925. Craycraft No. 3
926. Craycraft No. 4
927. Craycraft No. 5
928. Kerr, No. 1
929. Kerr, No. 8
930. Kariher Heirs No. 1
931. Kariher Heirs No. 2
932. Cisco, J.
933. Nelson, Alfred No. 5
934. Nelson, Alfred No. 4
935. Nelson, Alfred No. 3
936. Nelson, Alfred No. 7
937. Nelson, Alfred No. 2
938. Unknown
939. Williams, C. No. 13
940. Williams, C. No. 17
941. Williams, C.
942. Williams, C.
943. Williams, C. No. 16
944. Williams, C. No. 17
945. Williams, C. No. 1
946. Williams, C. No. 2
947. Williams, C.
948. Williams, C.
949. Williams, C. No. 4
965. Davis
966. Sherer, Jos.
969. Unknown
970. Unknown
971. Unknown
972. Unknown
973. Unknown
974. Crawford
975. Crawford
976. Unknown
977. Unknown
978. Unknown
979. Unknown
980. Unknown

NORTH SEWICKLEY TOWNSHIP

430. Blinn
431. Stephenson
432. Herman, Chas.
433. Pflug, Henry
434. Zimmers, John
435. Fombell
436. Walker No. 1
437. Morrow, Chas.

PERRY TOWNSHIP

440. Wurtemburg
441. Wurtemburg
442. Morrison Heirs
443. French
444. Riffer, P.
445. Hamilton

SHENANGO TOWNSHIP

450. Fallis
451. Warnock, J. M. No. 2
452. Warnock, J. M. No. 1
453. McCleary
454. Meyers, Rachel
455. Warnock, Heirs No. 1
456. Bell, James
457. Miller Heirs No. 2
458. Swagger, J. B.
459. Alburn
460. Lutton, Oscar
992. Unknown
993. Unknown
994. Unknown
995. Unknown
996. Unknown

SLIPPERY ROCK TOWNSHIP

465. Van Gorder, James, No. 1
466. Black, D. A.
467. Manning
468. Miller Heirs No. 1
469. Henderson
470. Wellhouser
471. Martin, George
472. Copper, Mrs., No. 1
473. Elliot, H. C.
474. Elliot, James No. 1
475. Elliot, James No. 2
476. Copper Bros.
477. Myers, Thos.
478. Aiken, W. F.
479. Alford, S. S.
480. Myers, G. W.
481. White, J. F.
482. White, R. W.
997. Unknown
998. Unknown

SOUTH BEAVER TOWNSHIP

490. Reed, J. Q. No. 1
491. Reed, J. Q. No. 2
492. Reed, J. Q. No. 1
493. Reed, J. Q. No. 2
494. Garvin, Elizabeth
495. Jenkins, W. & R. No. 1 (?)
496. Reed, J. Q. No. 1
497. Houston, James No. 1
498. Jenkins, W. & R. No. 2 (?)
499. Taylor, No. 1
500. Taylor No. 2
501. Taylor, Mrs. R. E.
502. Court Heirs
503. Graham, No. 3
504. Graham, William
505. Smith, Calvin
506. Garvin, Boyd
507. Conkle, J. E.
508. Scott, Joseph W. No. 1
509. Bradshaw, Thos. No. 1
510. Bingle, Wm. No. 1
511. Minch, Geo. No. 1
512. Long, Josiah No. 1
513. Long, Josiah No. 2
514. Bradshaw, Mary E. No. 2
515. Bradshaw, Mary E. No. 1
516. Fields, John
517. Bridges, T. B. No. 2
518. Logan, Matthew
519. Fields, John No. 2
520. Bridges, T. B. No. 3
521. Kerchgessner, H.
522. Dunlop Heirs, No. 1
523. Elder, James
524. Ferguson, Hugh
525. Louthan
526. Louthan
527. Sawyer, Frank
528. Elmer, Matthew No. 2
529. Elmer, Matthew No. 1
700. Taylor, R. E.
701. Graham, Wm.
702. Unknown
703. Unknown
704. Unknown
705. Unknown
706. Unknown

707. Unknown
708. Unknown
709. Reed, J. Q.
710. Weigle, M.
711. Bingle, Wm.
712. Brawshaw, T. J.
713. Behringer, A. K. & C. M.
714. Banks, M. C.
715. Bradshaw, M. E.
716. Bridges, T. B.
717. Bradshaw, Mary E.
718. Bridges, T. B.
719. Bridges, T. B.
720. Fields, J. F.
721. Fields, J.
722. Fields, D. S.
723. Fields, D. S.
724. Ferguson, H.
725. Ferguson, H.

TAYLOR TOWNSHIP

967. Unknown
968. Unknown

WAYNE TOWNSHIP AND ELLWOOD CITY

535. Pittsburgh Co.
536. Standard Engineering Co.
537. Burns, Costin No. 1
538. Pittsburgh Co.
539. Burns, Costin No. 3
540. Burns, Costin No. 1
541. Burns, Costin No. 2
542. Peerless Glass Co.
543. Pittsburgh Co.
544. Pittsburgh Co.
545. Ellwood City Glass Co.
546. Pittsburgh Co.
547. Matheny, E. J.
548. Cole
549. Pittsburgh Co.
550. Hazen, John B.
551. Johnson, Jordan
552. Wilson, John P. No. 2
553. Deemer lot
554. Deemer, Albert
555. Deemer, Sampson
556. Mehard, Joseph
557. Mehard, Joseph
558. Liebendorfer, E. W. No. 1
559. Mehard, W. M. No. 1
560. Mehard, W. M. No. 4
561. Mehard, Margaret
562. Mehard, W. M.
563. Mehard, W. M.
564. Mehard, W. M. No. 2
565. Wilson (?)
566. Wilson, John P. No. 1
567. Johnson, Jordan
568. Hazen, John B.
569. Hazen
570. Hazen, John, B.
571. Nye
572. Newton
573. Cunningham, D. L. No. 2
574. Newton, P. No. 1
575. Connor, A. E.
576. Wallace, Mary A.
577. Newton, P., No. 2
578. Wallace, Mary A. No. 1
579. Wallace, Mary A. No. 2
580. Newton, P.
581. Ingham No. 1
582. Morrow No. 1
583. Newton, Wilbert
584. Guy
585. Mehard, W. M.
586. Smiley, James
587. Cunningham, James W. No. 1
999. Bena
1000. Bena.
1001. Unknown
1002. Unknown
1003. Unknown
1004. Unknown
1005. Unknown
1006. Unknown
1007. Young, Jno.
1008. Unknown
1009. Unknown

WHITE TOWNSHIP

595. Crozier, J. F.
596. Wagner No. 3
597. Wagner No. 4
598. Boswell, No. 1
599. Patterson, J. H. No. 2
600. Boyd, T. H. No. 1
601. Boyd No. 2
602. Harbison No. 1
603. Harbison No. 3
604. Harbison No. 1

605. Harbison No. 4
606. Whiteside No. 1
607. Whiteside No. 3
608. Parlington
609. Whiteside No. 2
610. Axle Co.
743. Unknown

MAHONING COUNTY, OHIO

265. Reiter, J. C.

WATER RESOURCES.

By J. Ross Corbin.

Waterworks systems supply to and distribute in the communities of New Castle, West Pittsburgh, Ellwood City, Wampum, Beaver Falls and Eastvale. Inasmuch as the sources of these supplies are the neighboring streams, the quantities are usually ample. The quality of the water may be very good, or it may require careful and extensive treatment to make it potable. Upstream contamination may be, and frequently is, a very serious factor particularly with reference to contamination by phenols, oils, and greases.

New Castle, situated at the junction of Mahoning and Shenango Rivers, draws its supply from the latter stream north of the city limits. Formerly the phenol wastes from the Farrell plant of the Carnegie Steel Company, at Sharon, caused many complaints about the taste of the water and some uneasiness as to its sterility. These troubles have been greatly reduced, however, by the installation of a phenol disposal plant by the Carnegie Steel Company.

Beaver Falls, and other communities which obtain their supply from Beaver River, are somewhat less fortunate; in fact, the Beaver River seems justly to have earned its name as the "worst river in Pennsylvania" as a source of potable water. Nor does it seem that the conditions can be easily altered, for many of the troubles originate in the contaminations which enter Mahoning River nearer its source, in Ohio. Plants at Youngstown, Ohio, for example, contribute largely to the unsavoriness of Beaver River water. At that locality no phenol disposal plant has as yet been put into operation. Consequently the wastes (particularly those of the Barrett Company) produce more or less unpleasant effects throughout the lower portions of Mahoning River and Beaver and Ohio Rivers.

A relation also exists between the river stage and the quantity and quality of contaminants. When the river stage is receding, or during low water, debris of various kinds accumulates along the banks and on the flood-plain. As the stage rises (and particularly in times of floods) this debris is carried downstream not only as scums but also as emulsions. To produce a pleasant-tasting potable water from such a supply is frequently very difficult, and ofttimes impossible.

PLATE XVII

A. Connoquenessing Creek near Ellwood City.

B. Beaver River at Beaver Falls, from east bank.

The enormously increased use of automobiles and motor trucks within recent years has added serious problems to the others with which the water companies are confronted. During dry weather the roads and streets accumulate the oils and greases which drip from passing vehicles. In times of storms these products are washed off the roads by the stormwaters, eventually finding their way into the main drainage channels. Added to these are the oily products carelessly (or otherwise) sent down the sewer pipes in garages; or washed off in the process of washing cars and trucks.

The variations in temperatures of the water and of the atmosphere produced by the seasons of the year have noticeable effects. During the warm weather of late spring, summer, and early autumn the more volatile, and somewhat more odorous, constituents are carried off by the atmosphere to such extent that their presence in the waters is markedly less noticeable than during the cooler seasons, when such atmospheric removal does not take place.

The variable discharge from coal mines, coke oven washings, and other industrial wastes causes the water supplies taken from the Beaver River to be of a highly irregular quality. A difficult phase of this is that the irregularities occur with unexpected suddenness. In the vicinity of Beaver Falls, for example, the supply may change from an alkalinity of 35 to 40 to alkalinity 4 in 12 hours. The pH values vary from about 5½ to about 7. The iron content may be 2 or 20 parts per million; and the hardness may range between 90 and 180. The latter, however, seems to depend somewhat on the manner in which the river stage affects the concentration.

To overcome these difficulties as far as feasible the various water companies have been compelled to exercise unusual care. In a nearby region a water company operates a water-softening plant (zeolite type) the result of which is reported to be a water having zero hardness. Although this may appear to be an unusual procedure it well illustrates the extent to which it is sometimes advisable to go in the treatment of these river waters for domestic use.

In the following paragraphs are some of the salient features of the waterworks systems which supply the cities and towns within the area of the New Castle quadrangle.

New Castle. The water for this city is supplied and serviced by The City of New Castle Water Company. This company was incorporated in 1902 as a merger of the following companies:

Name	Inc.	Inc. for
City of New Castle Water Co.	1881	New Castle
Mahoningtown Water Co.	1896	Mahoningtown
Shenango Water Co.	1897	Mahoningtown
West New Castle Water Co.	1896	West New Castle

The City of New Castle Water Company is owned by the American Water Works & Electric Co., New York.

The source of supply is the Shenango River, the intake and pumping station being about ¼ mile north of the city limits. The suction line, 20 inches diameter, serves two Root rotary pumps of 5,000,000 and 6,000,000 gallons daily capacity. The discharge from these pumps passes through a 20-inch pipe-line to a sedimentation basin of 1,000,000 gallon capacity located on hillside east of the pumping station. A 24-inch line conducts the water to the mechanical filter plant consisting of 16 units, 500,000 gallons each, from which the water passes into clear water basins, of which there are two. The capacities of these are 204,000 and 208,000 gallons. From the clear water basins the water is pumped to the high pressure service, and through a 20-inch force main to the low pressure distributing reservoir. The capacity of the latter is 6,335,000 gallons. It is located on the hilltop about ½ mile northeast of the pumping station.

Distribution is accomplished by two separate services, known as the high service and low service. The high service supplies that part of the city west of Shenango River, opposite and north of the mouth of the river, and the eastern part of the city. It is supplied by pumping a 12-inch main extending into the eastern part of the city and connected (8-inch) to an equalizing tank. The equalizing tank is located on a hill, and has a capacity of 220,000 gallons.

The low service supplies nearly the entire city. This supply comes by gravity through 16-inch and 12-inch mains from the distributing reservoir. The Mahoningtown section is supplied by a 10-inch line.

The average daily consumption is about 3,600,000 gallons. Of this about ¾ represents domestic consumption. Of the balance (25 per cent), classified as industrial consumption, the railroads require by far the larger quantity.

In addition to the foregoing there are several industrial concerns in New Castle which obtain their own water supply. These concerns, together with the source of water, are shown in the following tabulation:

Name	Source
New Castle Portland Cement Co.	Big Run
Dillworth Co. Paper Mill,	Neshannock Creek
Lehigh Portland Cement Co.,	Small nearby creek
Cold Storage plant,	Shenango River
Carnegie Steel Co., Rosena Furnace	Shenango River
Shenango Pottery Co.,	Shenango River
Standard Steel Car Works,	Shenango River

Beaver Falls, Patterson, College Hill. Beaver Falls, Patterson Heights, College Hill, and Eastvale are served by the Beaver Valley Water Company. This company also serves Bridgewater, East Rochester, Fallston, Freedom, New Brighton, and Rochester Boroughs, these being communities in the Beaver Valley in the vicinity (south) of Beaver Falls.

The first Beaver Valley Water Company was incorporated in 1899 to serve Beaver County. It was inactive, however, after 1902, and was dissolved in 1912. In 1901 the Conway Water Company was incorporated to serve Economy Township. In 1902 the name was changed, the stockholders having held stock in the following companies whose properties were leased to the Beaver Water Company for 999 years:

Name	Inc.	For
Beaver Valley Water Power Co.	1902	Beaver County
College Hill Borough Water Co.	1901	College Hill Borough
Fallston Water Co.	1902	Fallston Borough
New Brighton Water Co.	1838	(Special Act)
North Rochester Water Co.	1901	Rochester Township
Patterson Heights Water Co.	1902	Patterson Heights Boro.
Union Water Co.	1890	Beaver Falls Borough
Valley Water Co. of Rochester	1902	Rochester Borough
Westside Water Co.	1902	W. Bridgewater Borough

Beaver River furnishes the water for the water supply as well as a considerable part of the power for pumping. The company has two stations, one each at Eastvale and New Brighton (south of the New Castle quadrangle area). The station at Eastvale (across Beaver River from Beaver Falls) is located in the southern part of the borough. At that location a dam furnishes a head of about 11 feet for the operation of turbines. The equipment consists of 1 54-inch, 2 48-inch, and 1 39-inch turbines. These deliver 3,000,000-5,000,000 gallons per day, averaging about 4,000,000. The capacity of the equipment is about 6,000,000 gallons per day. During ordinary water stages sufficient water-power is available for pumping during about 10-11 months each year. To furnish a water supply during low stages, and as a reserve in the event of accident, reserve steam-electric equipment has been installed.

Water from the forebay also enters the pump well, from where it is pumped to a 600,000 gallon settling basin. The water is sterilized with chlorine. Lime and alum are used as coagulents. After the settling basin the water receives rapid sand filtration in ten 500,000 gallon units, from which it flows to a 260,000 gallon clear water well. From the later the water is pumped directly to the system through 12-inch and 16-inch lines. Ordinarily the Eastvale plant furnishes the supply for the system northward from New Brighton. At College Hill is a 4,000,000-gallon equalizing reservoir, and a 60,000 gallon tank 80 feet higher, fed by a booster station. There is also a 1,000,000-gallon reservoir in the Mt. Washington (northwestern) section of Beaver Falls. A reservoir west of Patterson Heights is also part of this service. Of the service about 80 per cent is for domestic use, the balance being taken by industrial consumers.

In addition to the foregoing there are several industrial concerns in Beaver Falls which obtain their own water supply. These concerns, together with the source of water, are shown in the following tabulation:

Name	Location	Source
American Axe and Tool Co.	Beaver Falls	Beaver River
Ames Shovel Co.	Beaver Falls	Beaver River
Standard Connecting Rod Co.	Beaver Falls	Beaver River
Mayer Pottery Co.	Beaver Falls	Beaver River
Valley Ice Co.	Beaver Falls	87′ well in gravel
Penn Bridge Co.	College Hill	Drilled well
Pittsburgh Seamless Tube Co.	College Hill	Beaver River

Ellwood City. The Ellwood Water Co. serves Ellwood City. This company, incorporated in 1892 for Wayne Township, has recently been purchased by Gannett, Seelye & Fleming, Harrisburg, Pennsylvania. Extensive developments are planned. The water which this company supplies is taken from Slippery Rock Creek, near its mouth. From the pump well the water is pumped to a settling basin of 380,000 gallons capacity from which it goes to mechanical filters of which there are 4 units, each having 750,000 gallons capacity. After passing through the filters the water goes to the clear water basin (capacity 145,000 gallons) from which it is pumped directly to the distributing system. An equalizing reservoir, south of the borough, has 6,000,000 gallons capacity. About one-fifth of the consumption is domestic, the balance being used in industries, a small amount (5 per cent), being used for washing the filters. Of the industrial users the Shelby Steel Tube Company is by far the largest consumer.

West Pittsburg. In 1902 the West Pittsburgh Water Company was incorporated for Taylor Township. The waterworks were built in 1905. The company is owned by the West Pittsburgh Realty Co., a subsidiary of the Garland Corporation of Pittsburgh. Water is taken from Beaver River and pumped directly into the distributing system. Connected to the system are 3 equalizing tanks with capacities of 20,000 gallons, 56,000 gallons, and 65,000 gallons. The average daily consumption of 65,000 gallons is used about equally for domestic and industrial purposes.

PLATE XVIII

A. Hickory Run at Mt. Jackson. Granite boulders brought from Canada by a glacier are common here.

B. Shenango River at New Castle.

Wampum. In 1911 the municipality installed an 18,000-gallon receiving tank and an electrically driven pump for the purpose of fire protection. The water supply is obtained from springs at the northern part of the borough by a loose-joint terra cotta pipe gathering system. The gathering pipes are 24 inches in diameter. From the receiving tank the water is conducted 500 feet through cement jointed 6-inch terra cotta pipe to the pump well from which it it is pumped directly to the distribution system. The distributing system is of 6-inch and 4-inch pipe, approximately three-fourths of it being of the larger size. The system is connected to a 200,000-gallon equalizing reservoir.

Bessemer. Bessemer water supply is from 7 wells about 200 feet deep owned by the Bessemer Lime & Cement Co. which furnishes the town and industries. The water is softened and pumped to two steel tanks on nearby hills. Most of the company houses have running water. The village has no sewer system but some septic tanks are in use.

The other towns and villages within the area represented by the New Castle quadrangle depend upon individual sources for supply. For this purpose driven wells, dug wells, and springs are employed numerically in about the order given. It is not by accident alone that Darlington, New Galilee, Enon Valley, North Sewickley, Wurtemburg, and Union Valley are located where potable water may be easily obtained; rather, the locations of these settlements (and others) indicate the control which geologic factors exercise upon human actions.

Occurrence of Underground Water.

The valley of Little Beaver Creek, and the valleys of its tributaries, Honey Creek, Beaverdam Run, Madden Run, and Painters Run, are composed of, or underlain by glacial debris and alluvium. The glacial debris is a heterogeneous mass of boulders, pebbles, and sands of various sizes, the whole being indiscriminately mixed. Material of this kind, in large quantities, forms natural sand filters which approach the ideal. The masses are usually sufficiently porous to permit the flow of water in large quantities, yet the pores are sufficiently small to remove, by filtration, the mechanical impurities of the underground water.

Alluvium, as contrasted with the glacial material, is essentially composed of water-transported fragments; consequently sorting actions have taken place. The material may represent the weathered, disintegrated products of coherent bedded deposits, or it may represent glacial debris which has been resorted and reclassified by stream action. In either case owing to the classifying action of moving water a somewhat uniformity of size of individual units is exhibited. Accordingly, gravels, sands, silts and muds will be segregated. The sequence in which these are found will depend upon the sequence of the stages of the stream, the quantities of material deposited, the temporary local grade of the watercourse, and other factors. The subject is one whose fundamentals are simple and well understood; but in its practical application great complexities arise which demand exhaustive local study for coherent interpretation. The net results of the various factors involved are the "bottom lands" of some of the valleys.

In the event that the stream maintains a definite channel for a protracted time period the channel will gradually be deepened provided there is sufficient gradient to cause reasonably rapid flow of the stream, and provided further that the stream--waters carry small particles, such as sand-grains, which may abrade or corrade the stream-bed. Under such circumstances, what were previously "bottom lands" may later be recognized as stream terraces.

Of the alluvial material the sands and gravels perform the functions of natural filters or of natural reserviors, depending upon whether the location is above or below ground-water level. The effect of silts and clays is that of preventing the passage of water, because the interstices are so minute. Inasmuch as the silt and clay deposits are approximately horizontal, they impede the vertically downward movement of the ground-water; and sands and gravels lying above beds of silt or clay become, in effect, reservoirs. The interstices between pebbles are much larger than those between sand-grains; hence gravels permit less restricted flow of the storage-water than do sands. The effective quantity of water available, however, will depend upon the extent (both vertical and horizontal) of the porous bed and the constancy and proximity of the source.

The conditions most frequently met with are those where the sands and gravels (or weathered fragments of the consolidated rocks) rest directly upon the rock surfaces. Under such conditions the rock surfaces are comparatively impermeable, and although the rock surfaces may be very irregular in outline, they prevent or impede the water moving vertically downward. Water circulation through the unconsolidated material lying above is downward, and toward drainage (stream, creek, or run). Should the consolidated rock (bedrock) crop out or come close to the surface it will tend to divert the groundwater towards the surface also. When the groundwater appears at the surface the term "spring" is applied.*

For a full discussion of the principles and details of the occurrence of ground water see Meinzer, O. E., The Occurrence of Ground Water in the United States. U. S. G. S. Water-Supply Paper 489, Washington, D. C., 1923.

All these conditions are usefully exploited within the area represented by the New Castle quadrangle. The best watergiving material is the coarser type of gravel. Gravels which have been subjected to the action of running water have been classified and permit the flow of ground-water rather freely. As the size of the material becomes smaller the flow is restricted, a fine sand yielding much less flow than coarser material. Glacial-borne material, if of uniform or approximately uniform size, offers excellent source for supplies for domestic use. If, however, the interstices between the larger boulders are filled with gravels, and the interstices of the gravels filled with sand, and the interstices between the sand grains, in turn, filled with "rock flour" the water flow may be so restricted as to be unsatisfactory. Examples have occurred within the New Castle area where the rock material was so finely divided that it accompanied the water from that particular horizon, forming "mud flows" which caused the abandonment of water wells.

The buried river and creek channels have been of considerable importance in the past in furnishing domestic supplies of water within the New Castle quadrangle, and in the future they may be even more important. These buried channels owe their existence to a noteworthy combination of circumstances. They began forming when the land surface was raised above water-level, and the streams deepened their courses throughout the long geologic ages whose sequence followed. During this time interval the stream-bottoms were lowered 150, 200, or more feet below the present drainage levels. At this stage of development the main streams, Beaver River and Little Beaver Creek, flowed northward, being part of a drainage system which flowed oceanward through what is now Lake Erie.[1] During the advance of the ice sheets in recent times, however, tremendous quantities of loose material were brought down from the north and deposited in the area covered by the ice-sheets, and in particularly large quantities along the southern edge of the ice sheets. The ice, in conjunction with the material which it deposited, dammed the northward-flowing streams, forming a series of reservoirs. As the water levels rose the water-covered areas extended farther and farther back and away from the valleys. Reaching low passes in the surrounding grades, the reservoirs found outlets; from which were developed new courses. Coincident with these phenomena large quantities of sand and gravel were deposited in the previously existing water-courses, filling them far above their former levels.

With the disappearance of the ice-sheets the net results of all these factors were such pronounced features as changes in the courses of the streams, elevations of stream-bottoms, and changes in direction of streams. Stream piracy, also, may have been locally important. Changes in the relations between sizes of streams and sizes of the valleys through which they flow are therefore apparent in many examples.

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[1] Leverett, Frank. Glacial formations and drainage features of the Erie and Ohio Basins. U. S. Geol. Survey Monograph Vol. XLI. Washington, 1902.

Regarding these drainage changes Frank Leverett, of the U. S. Geological Survey, wrote as follows on October 5, 1927:

"The old conception that the part of the Ohio along the border of the Panhandle of West Virginia drained northward to the Beaver until reversed by the advance of the ice in the earliest stage of glaciation is open to question for two reasons. First, the Ohio appears to cross an old divide near Smiths Ferry a short distance east of the west line of Pennsylvania where bluffs rise precipitously nearly 600 feet above the present stream and drainage west of it points westward. Second, the part of the Ohio along the border of the Panhandle does not have evidence of ponded water in form of silt and clay deposits such as are so conspicuous on the Monongahela as a result of ponding of its waters. Much of the Little Beaver drainage had a northward discharge to Big Beaver below the junction of the Mahoning and Shenango, but the lower end, together with the drainage west of Smiths Ferry, may have discharged down the present course of the Ohio. As an alternative interpretation it is suggested that a small section of the Ohio between Wellsville, Ohio and Smiths Ferry, Pennsylvania discharged northward through Little Beaver, and only that part below Wellsville discharged southward."

The accompanying map (Plate II) shows the areas over which glacial drift and stream-deposited material are to be found. Deposits along the valley of Beaver River might well be expected. Of exceptional interest, however, are the deposits indicated along the valley of Little Beaver Creek and its tributaries, Beaverdam Run and Honey Creek. The continuity of part of these deposits with those along Hickory Run is significant.

The depths of these deposits are of considerable economic interest. In the vicinity of Mt. Jackson, for example, at a locality considerably removed from any present large drainage system, reports of wells indicate the thicknesses of the gravels. In a few instances wells were sunk in places where the gravels were only 10-20 feet thick. However, the majority of the well records indicate thicknesses of 40- to 75 feet. Similar thicknesses are indicated elsewhere in the area. In the vicinity of Beaver Falls, for example, the old channel of the Beaver River lies to the west of the present channel; and the old channel contains 80 feet or more of unconsolidated material. The Valley Ice Company, Beaver Falls, secures water from gravel at 87

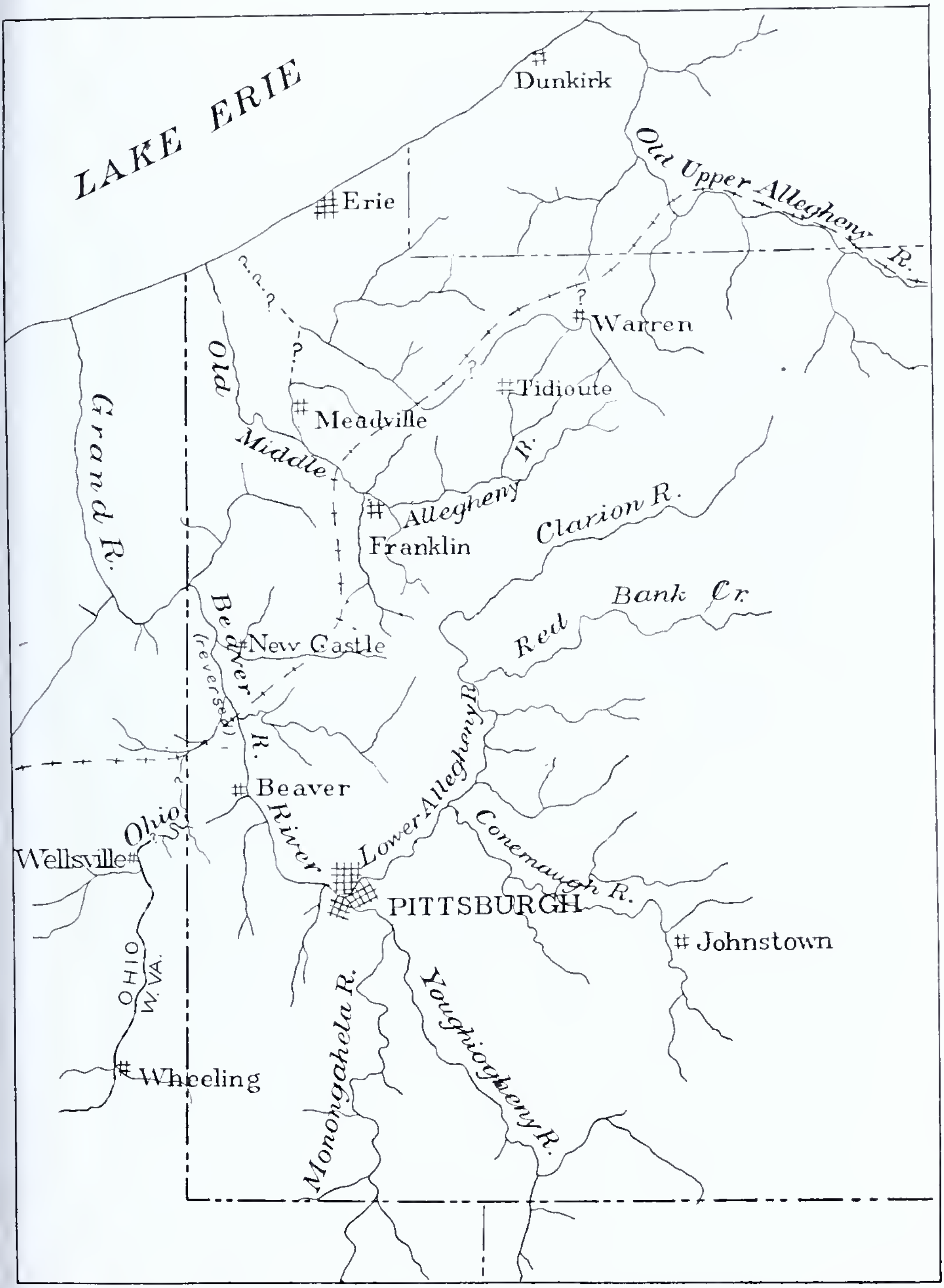

FIGURE 17. Map showing probable pre-glacial drainage of western Pennsylvania.

feet depth. In places Mahoning and Shenango rivers are now flowing over beds of sand and gravel 150 to 200 feet thick which fill the ancient beds of these rivers.

Wells located in situations such as the foregoing will furnish water in quantities ample for domestic and live stock purposes; and if especially favorable conditions obtain flows of many thousands of gallons per day may be had.

Many wells supplying water for domestic use are located elsewhere than in those regions where gravel is abundant. In no case known is the supply inadequate for ordinary domestic purposes. The quality of the water obtained in this manner is usually good, but not invariably so. If the well is so located that it receives the drainage from a coal-bed which contains considerable pyrite, the water obtained from the well may contain a noticeable quantity of iron. Such situations, however, are very unusual and have generally been avoided.

Deep wells. Nearly all of the manufacturing plants requiring large quantities of water are located in such situations that their water supplies are obtained from streams which drain the area. In only very few instances have deep wells been drilled for the purpose of obtaining water supply. The logs of wells sunk in oil or gas developments have indicated the presence of water, usually salty, in several localities and at rather indiscriminate horizons. Of the instances where aquifers have been found the pressure has usually been insufficient to cause a noteworthy rise of the water level in the well. In one instance in North Beaver Township, water which was struck at 633 feet depth is reported to have risen about 500 feet. So far as known, this is the greatest height to which water has risen in deep wells within the area. There are no deep flowing wells here.

Waters obtained from the rocks which are exposed within the quadrangle are usually satisfactory with the exception of the hardness, which varies according to location, and somewhat with the season. Modern water-softeners, of the zeolite type, offer relief from this aspect should it be seriously objectionable. Water-bearing strata in the deeper underlying rocks are seldom encountered; and water from such strata, when found, usually contains too much dissolved mineral matter to be used, particularly inasmuch as other sources are available.

The Conemaugh group, of which only the lower 210 feet remain, contains sandstones which yield considerable potable water. Of the sandstones in this formation the Mahoning sandstone is a good aquifer. Where it occurs within the southern part of the area it is at comparatively shallow depths, and in such places it may well be worth exploration should a source of this kind be necessary.

The Allegheny group, 265-325 feet thick, consists largely of sandstones and shales in which are several coal beds. Both sandstones and coal beds may be water-bearing. Owing to the presence of pyrite, water obtainable from the coal beds may require treatment before use. In localities outside of the New Castle area potable water has been obtained from clays underlying the coals. No such expedient has been necessary within this area, however.

Whether coal horizons are water-bearing or whether they behave as seals, preventing the further downward movement of the water, will depend upon the internal structure of the coal bed. The water well on the John Kyle property, No. 450, obtains water just over the Middle Kittanning coal. Again, a spring marks the horizon of the Middle Kittanning coal above West Pittsburgh. On the James Elder place, No. 267, the horizon of the Lower Freeport coal is probably represented by a spring. On the Riddle farm, No. 419, a spring indicates the horizon of the Lower Kittanning coal. Other illustrations could undoubtedly be found within the area.

The Pottsville series contains sandstones with variable physical characteristics, essentially massive. It contains several aquifers the Lower Connoquenessing sandstone being an excellent example. In the New Castle area the group is exposed only along the valleys of Beaver River and Connoquenessing Creek. and there as massive cliffs; the population dwelling on or near its outcrop is therefore very limited. For those who so dwell, however, it supplies ample quantities for domestic use at shallow depths. Elsewhere in the area other sources are used. The Pottsville series is not exposed in its entirety within the area, and its lower limit is somewhat doubtful.

The Mauch Chunk shale is probably not present beneath this area. From time to time it has been tentatively identified from drill cuttings; but if present it is probably in the form of small patches. It is unimportant as a source of water.

The Pocono sandstone has very indefinite boundaries within the New Castle area partly because of confusion in identifying drill-cuttings, necessarily difficult, and partly because of an erosional uncomformity at its top. The base of the Pocono has been tentatively accepted as being the base of the Gas sand.

The Catskill formation has been tentatively assigned those rocks from the Bedford red shale, immediately below the Gas sand, indefinitely downward.

The identification and correlation of the unexposed rocks in this area (those below the Sharon coal) leave much to be desired. In general the Berea and Gas sands, 150 - 200 feet thick, are easily recognizable. The 325 feet of beds above these are variable. They are largely sandstones, but contain also some shaly sandstones or shales. Below the Berea and Gas sands, for the distance as far as has been disclosed by drilling (about 2200 feet), occur the variable beds of the Catskill formation. This formation is characteristically one of red shales although local sandstone lenses have been penetrated.

In the operations of sinking wells from which it was hoped to obtain oil or gas it was not unusual to find that the sands contained water. The Lower Connoquenessing (?) sandstone, locally called the "Big Injun" or "Mountain sand" was frequently found waterbearing. This is the lowest massive bed exposed in the New Castle area; its top is 200-300 feet below the Middle Kittanning coal. Three to four hundred feet lower the Berea (Amber sand) was frequently found to be saturated with water. The elevation of the water line is approximately 310-340 feet; in the vicinity of Mahoning River the sand has been found to be wet as high as 450 feet. There seems to be no uniform line of saturation. The Gas sand, whose top is 40-90 feet below the top of the Berea, was found to be very wet just below the gas horizon. The water obtained from these horizons was usually reported as "salt water"; in the presence of gas or oil it contained emulsified or dissolved hydrocarbons.

Effect of structure. Inspection of the relation between the oil and gas pools and the structure contours, as shown on map Plate V indicates that the pools and fields do not strictly coincide with the structural relations mapped. This suggests that the structure of the deeply buried rocks does not coincide precisely with that of the horizon upon which the structure contours are based. This observation is a common one in Pennsylvania. Because of this non-coincidence it is extremely difficult accurately to foretell in all cases the results of drilling. The anticlinal theory of oil and gas accumulation was proposed and accepted, in principle, many years ago. From time to time additions to this theory, or correlaries, have appeared, and in numerous instances results of drilling have verified the deductions previously made. With restrictions which are enforced by local conditions these theories and hypotheses become useful tools in prognosticating the possibilities of ground water developments.

Ground water will be found in greatest quantity, and at greatest static pressure along the axes of synclines. The porosity of the aquifer, however, may be such as to impede the free flow of water from the water-bearing stratum into the bottom of the well. Another very favorable situation for water-wells is along a steeply dipping limb of a syncline, or on the lower part of a steeply dipping limb of an anticline. Inspection of the structural contour map of the New Castle area indicates that the most favorable locations for deep water wells in that vicinity are

(1) The synclinal basin southwest from Darlington
(2) Southeast of a line between North Sewickley and Beaver Falls
(3) The area between Ellwood City and West Pittsburgh
(4) The vicinity of New Castle.

Quality of water to be expected. Experience has shown that water obtained from rocks such as underlie the New Castle area will be potable provided the situation is such that the rocks are near the surface. Water obtained from these rocks when deeply buried is more or less salty or mineralized. The salts which are in solution are largely common salt (sodium chloride, $NaCl$), although calcium chloride ($CaCl_2$) may be present in noticeable quantities. Besides these there may also be present potassium and magnesium, and bromine and the sulphate radicle. When these materials are present in sufficient quantity such water may be classed as a brine. In the past such brines offered possibilities of commercial exploitation as sources for various salts. The last of these producers in Pennsylvania discontinued operations in 1914 and such operations are no longer profitable.

Summary.

(1) The cities, towns, and some of the individual industries located along Beaver River and its tributaries receive supplies from the streams. These supplies are settled, filtered, and distributed by and through standard appliances and methods.

(2) Upstream contamination offers serious problems. This is particularly true as regards phenol waste products from plants located in Ohio. The interstate aspect of this problem is discouragingly difficult.

(3) The communities located away from Beaver River valley depend upon local sources for supplies.

(4) Well sorted river gravels, and sands; glacial debris; and soils, in the order named, furnish the water usually necessary for domestic uses.

(5) In portions of the area buried valleys, produced as a result of glacial invasion, are especially good sources of water.

(6) Deep wells for water supply have so far been unnecessary.

(7) The underlying strata contain several good aquifers, as shown by logs of oil and gas wells.

(8) A definite relation may be presumed between underground rock structure and best location for deep water-wells. The area contains several favorable localities.

(9) Where aquifers are encountered in Paleozoic rocks the water obtained from them will be more salty with increase in depth.

(10) The mineralization of the deeper waters is essentially salts of sodium, magnesium, potassium and calcium with chlorine, bromine, and the sulphate radicle.

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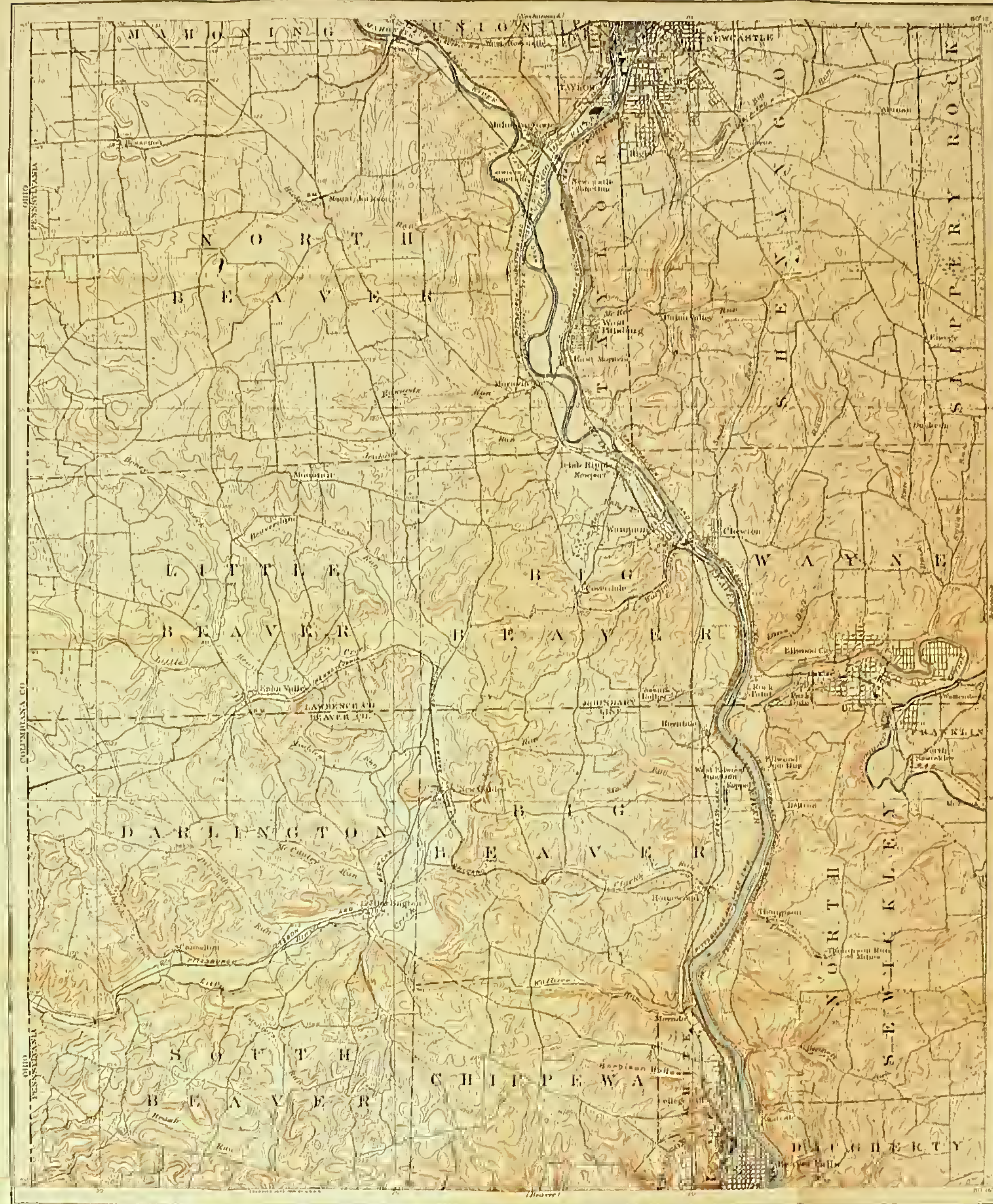
TOPOGRAPHIC AND GEOLOGIC SURVEY
GEORGE H ASHLEY, STATE GEOLOGIST

TOPOGRAPHIC AND GEOLOGIC
ATLAS OF PENNSYLVANIA
NEW CASTLE QUADRANGLE
SHEET 5 PLATE I



Base from U. S. Geological Survey topographic map
of New Castle quadrangle, Pennsylvania
Surveyed in cooperation with the
State of Pennsylvania in 1901–1902

MAP OF THE NEW CASTLE QUADRANGLE, PENNSYLVANIA AND PART OF THE COLUMBIANA QUADRANGLE

Scale 1:62500

Contour interval 20 feet
Datum is mean sea level
1928

U. S. GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

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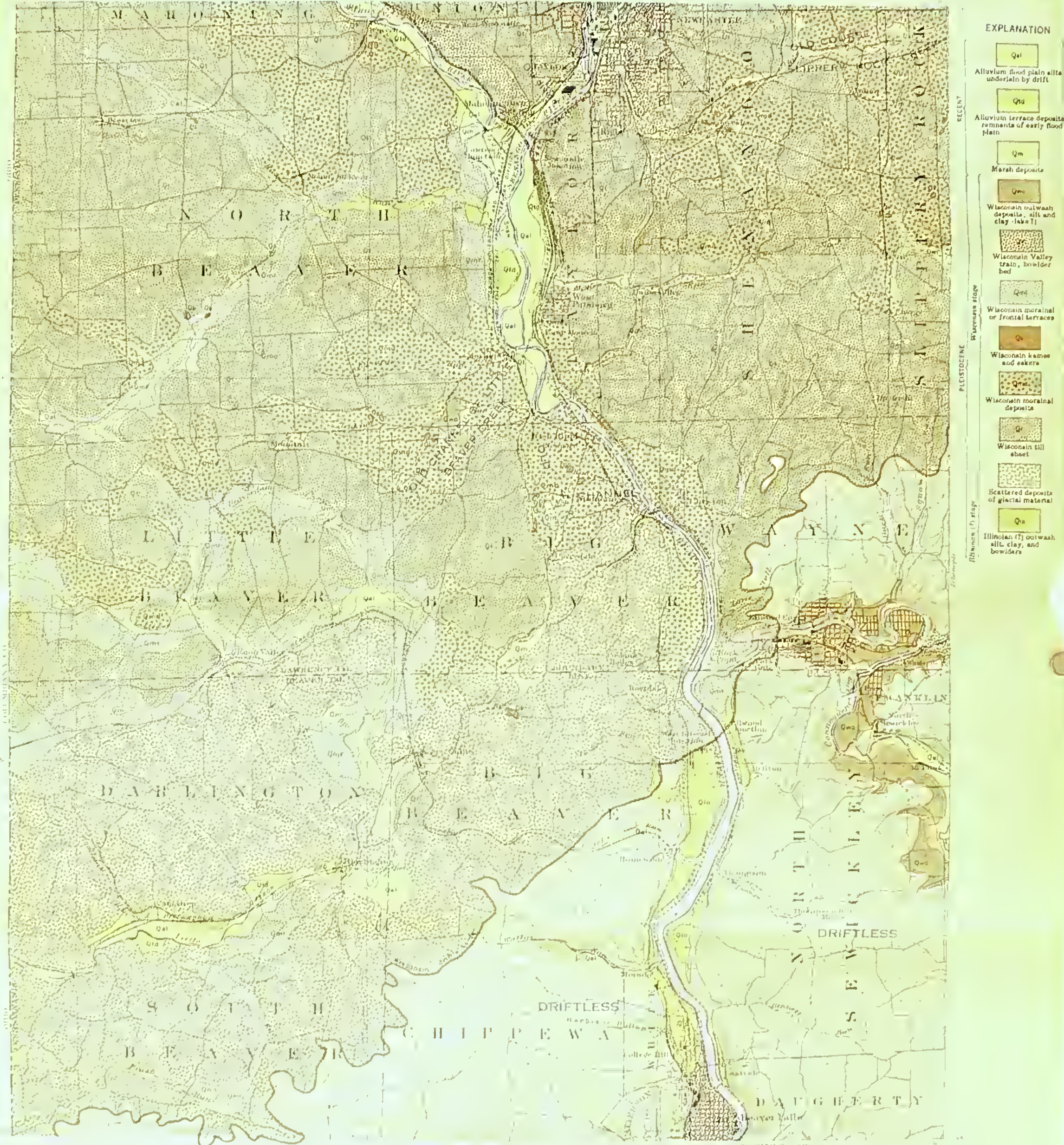
TOPOGRAPHIC AND GEOLOGIC
ATLAS OF PENNSYLVANIA
NEW CASTLE QUADRANGLE
SHEET 5 PLATE II


MAHONING
NORTH BEAVER
LITTLE BEAVER
BIG BEAVER
DARLINGTON
SOUTH BEAVER
CHIPPEWA
WAYNE
FRANKLIN
NORTH SEWICKLEY
DAUGHERTY
SHENANGO
SLIPPERY ROCK CREEK
OLD CHANNEL
DRIFTLESS
DRIFTLESS
EXPLANATION
RECENT
PLEISTOCENE
Wisconsin stage
Illinoian (?) stage
Qal
Alluvium flood plain silts underlain by drift
Qtd
Alluvium terrace deposits remnants of early flood plain
Qm
Marsh deposits
Qwo
Wisconsin outwash deposits, silt and clay (lake?)
Qvt
Wisconsin Valley train, bowlder bed
Qmf
Wisconsin morainal or frontal terraces
Qk
Wisconsin kames and eskers
Qmd
Wisconsin morainal deposits
Qt
Wisconsin till sheet
Scattered deposits of glacial material
Qio
Illinoian (?) outwash silt, clay, and bowlders

Base from U. S. Geological Survey topographic map of New Castle quadrangle, Pennsylvania, surveyed in cooperation with the State of Pennsylvania in 1901-1902

MAP OF THE NEW CASTLE QUADRANGLE, PENNSYLVANIA
SHOWING SURFICIAL GEOLOGY

Scale [illegible]

Miles

Kilometers

Contour interval 20 feet

Datum is mean sea level

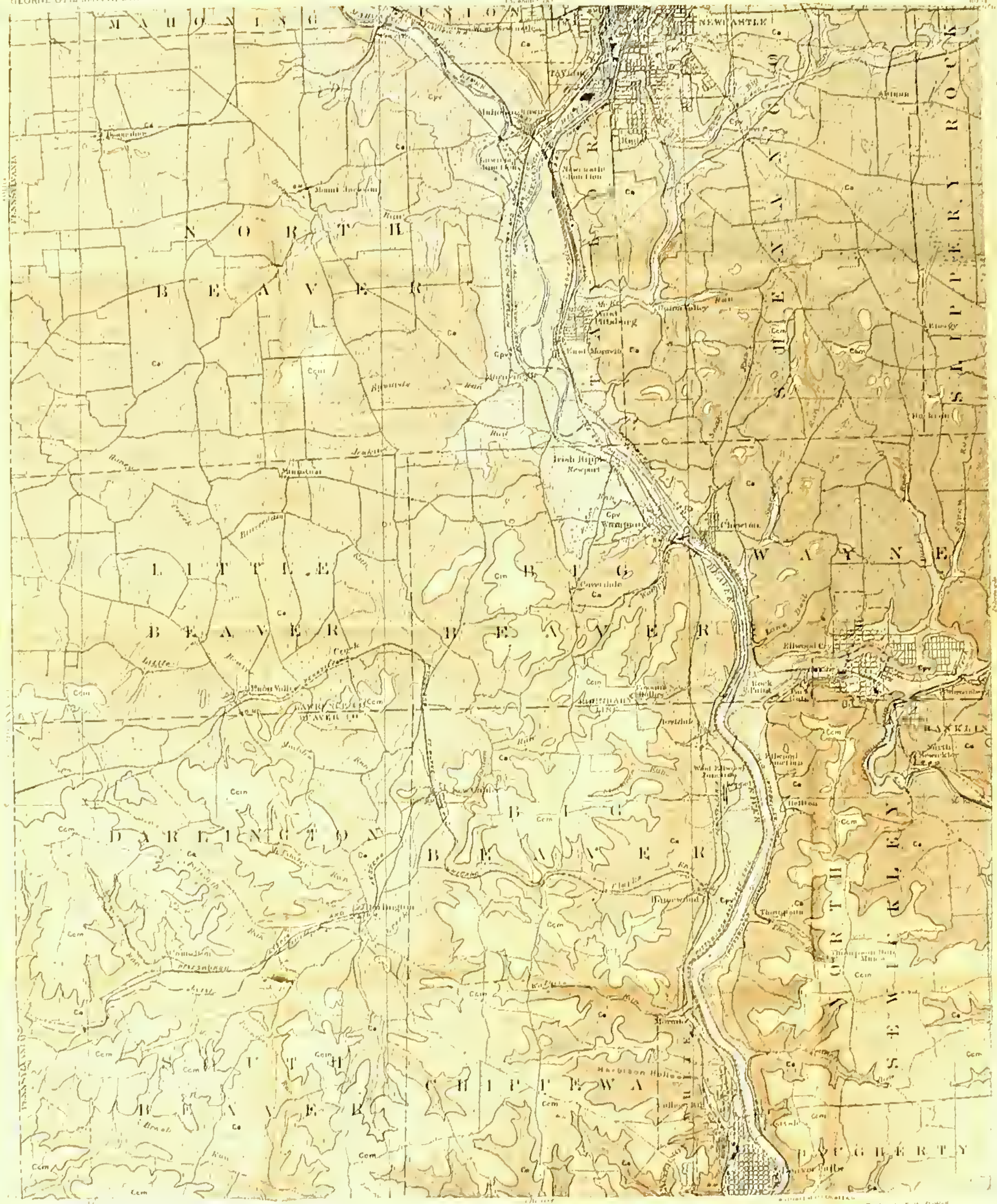
1928

Geology by F. W. DeWolf, 1905-1906 for the U. S. Geological Survey, in cooperation with the Topographic and Geologic Survey Commission of Pennsylvania

U. S. GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

PENNSYLVANIA DEPARTMENT OF INTERNAL AFFAIRS
JAMES F. WOODWARD, SECRETARY
TOPOGRAPHIC AND GEOLOGIC SURVEY
GEORGE H. ASHLEY, STATE GEOLOGIST

TOPOGRAPHIC AND GEOLOGIC
ATLAS OF PENNSYLVANIA
NEW CASTLE QUADRANGLE
SHEET 5 PLATE III



EXPLANATION

Ccm	**Conemaugh group** (Sandstone, sandy shale, and shale with a few coal beds)
Ca	**Allegheny group** (Shale and massive sandstone with beds of limestone, coal and fire clay)
Cpv	**Pottsville series** (Coarse massive sandstone and fine conglomerate, often shaly at top. Contains thin coals and limestones)

N. B. Owing to alteration of preglacial topographic forms (erosion and deposition of uncertain thicknesses of material) by glacial action, the Conemaugh formation may be present in some of the areas shown as such in the northern portion of the quadrangle. This uncertainty is indicated by dotted boundaries. Likewise the present location of the Allegheny-Pottsville boundary is uncertain in the northern portion of the area. Drill holes in the vicinity of Mount Jackson indicate the position for this division [illegible] as shown by the dotted lines there. [illegible] elsewhere are probably very much less than the indicated near Mt. Jackson.

Base from U. S. Geological Survey topographic map of New Castle quadrangle, Pennsylvania. Surveyed in cooperation with the State of Pennsylvania in 1901-1902

MAP OF THE NEW CASTLE QUADRANGLE, PENNSYLVANIA
SHOWING AREAL GEOLOGY

Geology by F. W. DeWolf, 1905-1906 for the U. S. Geological Survey in cooperation with the Topographic and Geological Survey Commission of Pennsylvania

Scale 1:62500

Contour interval 20 feet
Datum is mean sea level
1928

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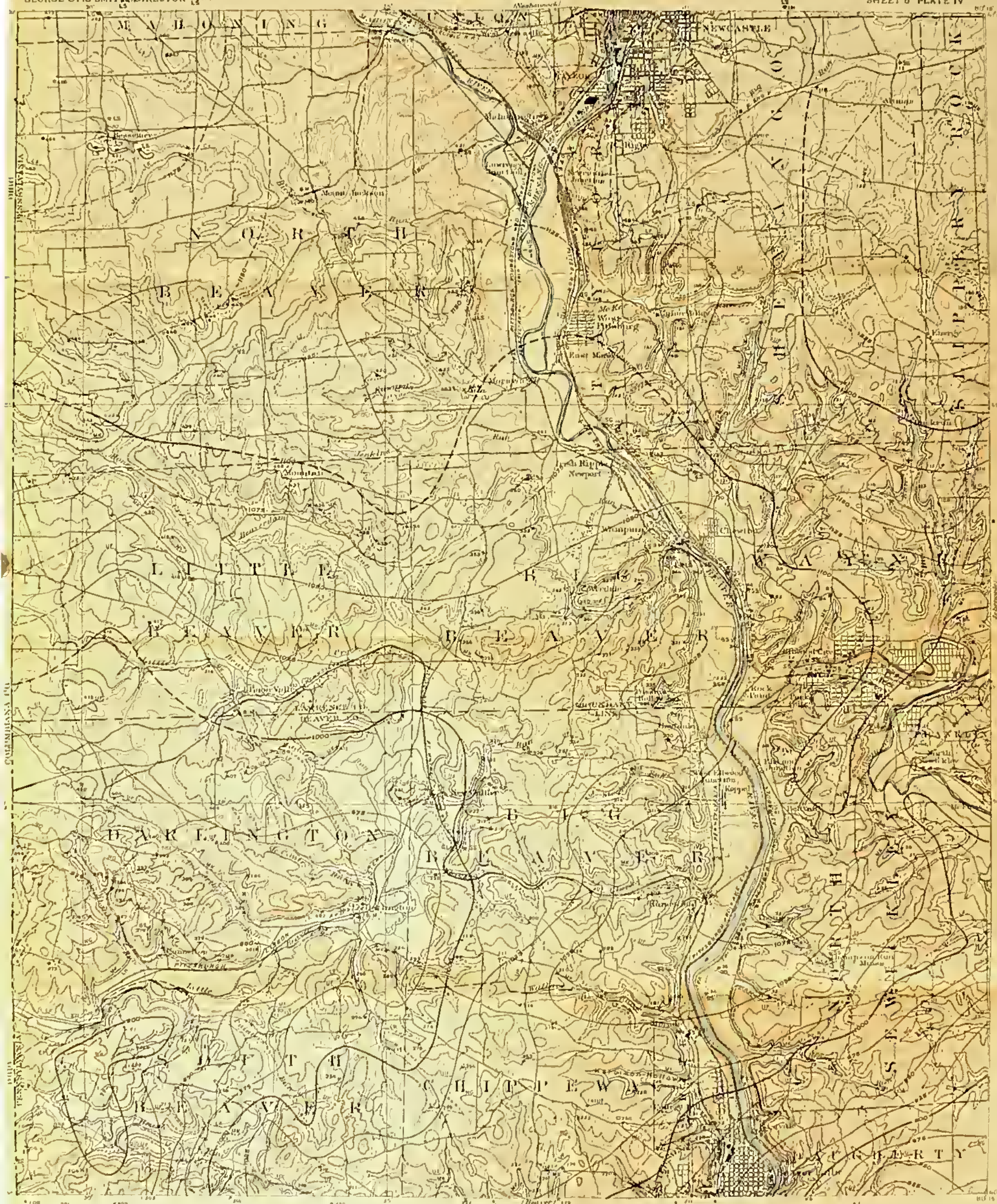
TOPOGRAPHIC AND GEOLOGIC
ATLAS OF PENNSYLVANIA
NEW CASTLE QUADRANGLE
SHEET 5 PLATE IV



EXPLANATION

Coal beds
(Broken line indicates approximate location)

- Coal shaft
- Coal mine (Active or inactive)
- Coal opening or country bank
- Location where coal has been observed

(Numbered mines or locations are referred to in text)

EP	East Palestine coal
UF	Upper Freeport coal
LF	Lower Freeport coal
MK	Middle Kittanning coal
LK	Lower Kittanning coal
C	Clarion coal
BV	Brookville coal
HW	Homewood coal
UM	Upper Mercer coal
LM	Lower Mercer coal

Vanport limestone
(Broken line indicates approximate location)

New Galilee clay

- Quarries and pits
- Location where limestone, sandstone or clay beds have been observed
- Bore hole

Numbered mines or locations are referred to in text

SS	Sandstone
LS	Limestone
CL	Clay
SH	Shale
SG	Sand or gravel
GR	Gravel

Structure contours on Middle Kittanning coal

Contour interval 25 feet

Datum is mean sea level

Base from U. S. Geological Survey topographic map of New Castle quadrangle, Pennsylvania
Surveyed in cooperation with the State of Pennsylvania in 1901-1902

MAP OF THE NEW CASTLE QUADRANGLE, PENNSYLVANIA
SHOWING ECONOMIC GEOLOGY AND STRUCTURE

Geology by F. W. DeWolf, 1905-1906 for the U. S. Geological Survey, in cooperation with the Topographic and Geological Survey Commission of Pennsylvania

Scale 1/62500
Miles
Kilometers

Contour interval 20 feet
Datum is mean sea level
1928

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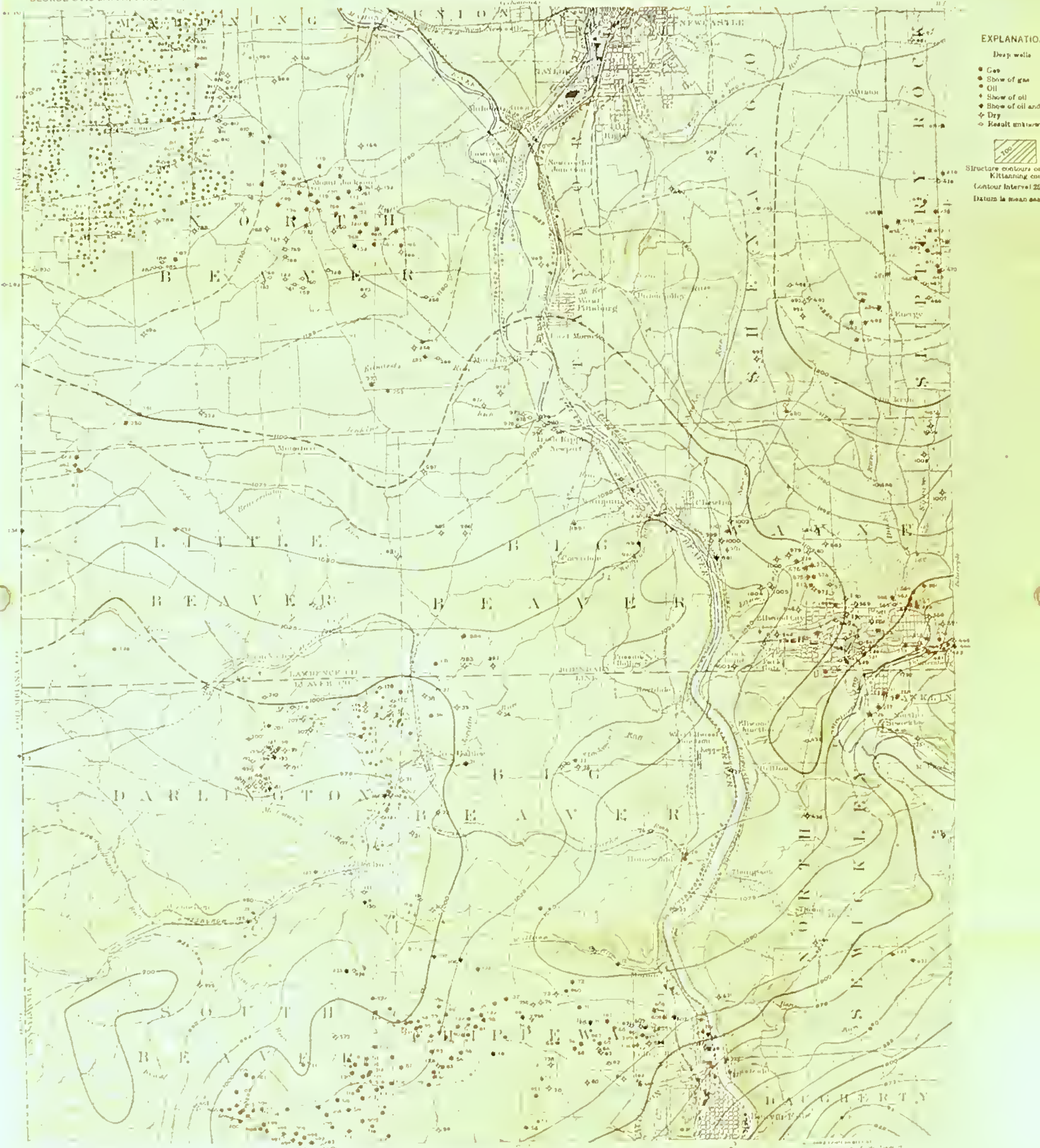
TOPOGRAPHIC AND GEOLOGIC
ATLAS OF PENNSYLVANIA
NEW CASTLE QUADRANGLE
SHEET 5 PLATE V



MAP OF THE NEW CASTLE QUADRANGLE, PENNSYLVANIA
SHOWING OIL AND GAS

Scale 1:62500

Contour interval 20 feet
Datum is mean sea level
1928